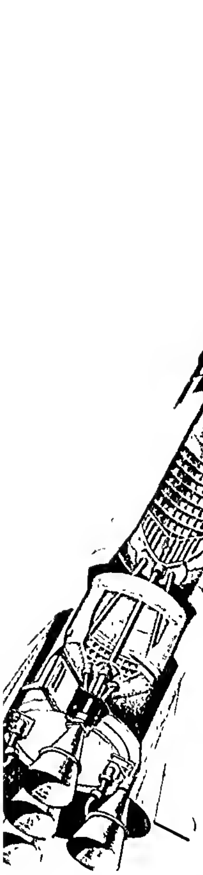
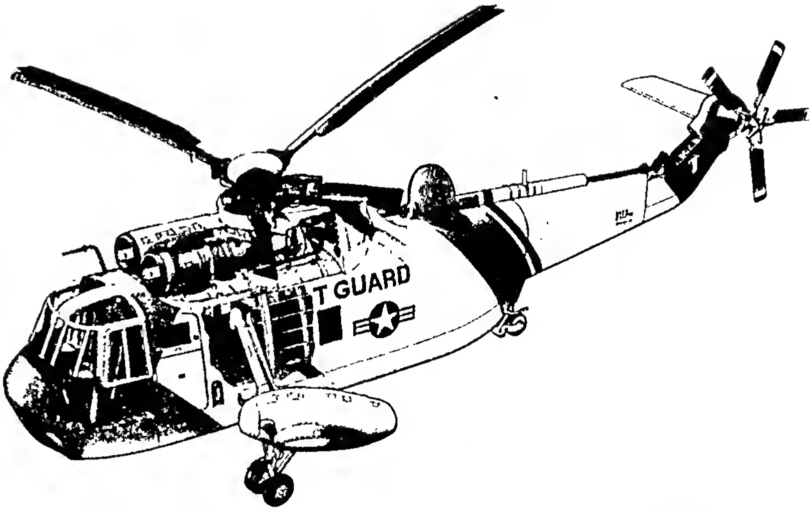
GROWING UP WITH SCIENCE

Volume 7

FORKLIFT TRUCK

HYDROFOIL





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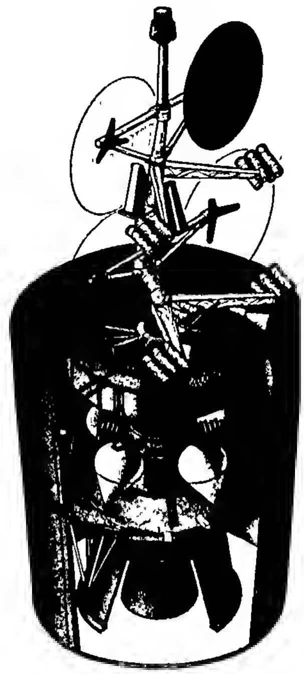
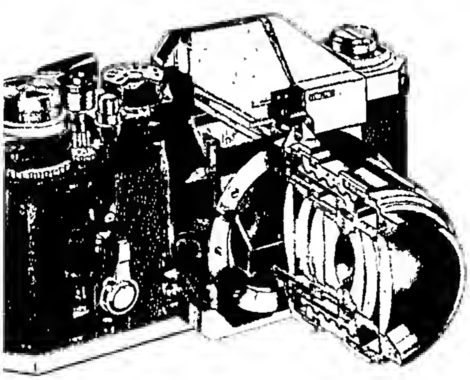
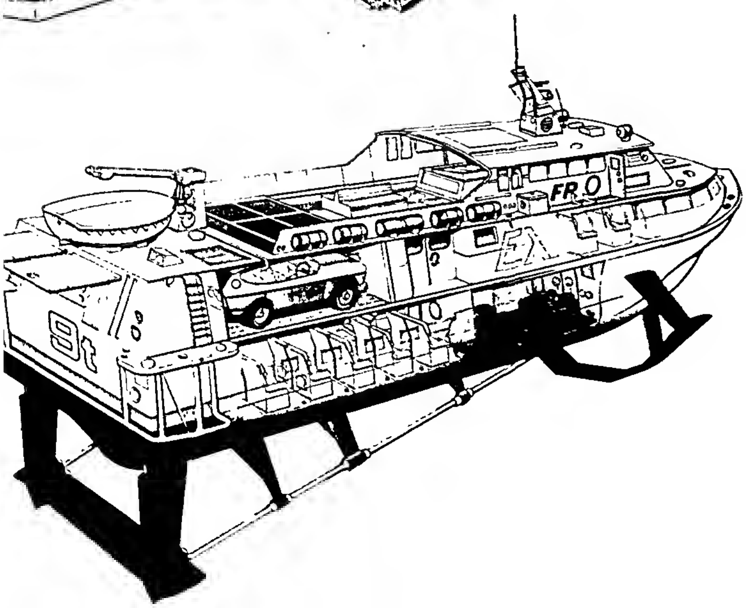
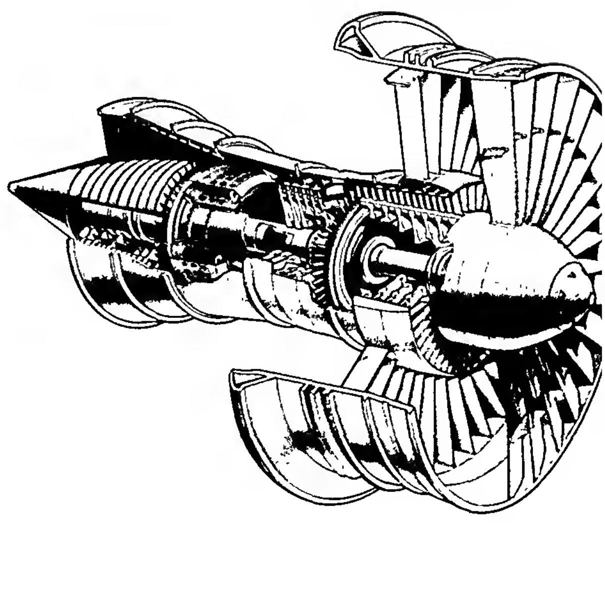


AN ALPHABETIC ENCYCLOPEDIA THAT ANSWERS
FOR YOUNGER READERS THE "HOWS," "WHATS" and "WHYS"
OF THE SCIENTIFIC WORLD IN WHICH THEY LIVE
AMONG SUBJECTS DISCUSSED IN THIS VOLUME ARE:



- Fossils
- Fuel Cell
- Gamma Rays
- Genetics
- Geology
- Glaciation
- Heart
- Helicopter
- Hydraulic Mechanisms





GROWING UP WITH SCIENCE

THE ILLUSTRATED ENCYCLOPEDIA OF INVENTION

VOLUME
7

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Forklift Truck

Forklift trucks are powerful machines used for handling heavy loads in small areas. They may be powered by diesel engines or electric motors. Some are designed to deal with fairly low-lying loads while others can be made to reach up to great heights.

Forklift trucks are used for handling all kinds of materials in factories, warehouses and other storage areas. A typical forklift truck has two forward-pointing prongs (the "fork"). The goods to be carried are usually stored on a pallet. This is simply a wooden stand with a space into which the prongs can be inserted. This method of transporting goods in a small area is quick and efficient. A forklift truck can carry many times the load that a man can carry.

General purpose trucks

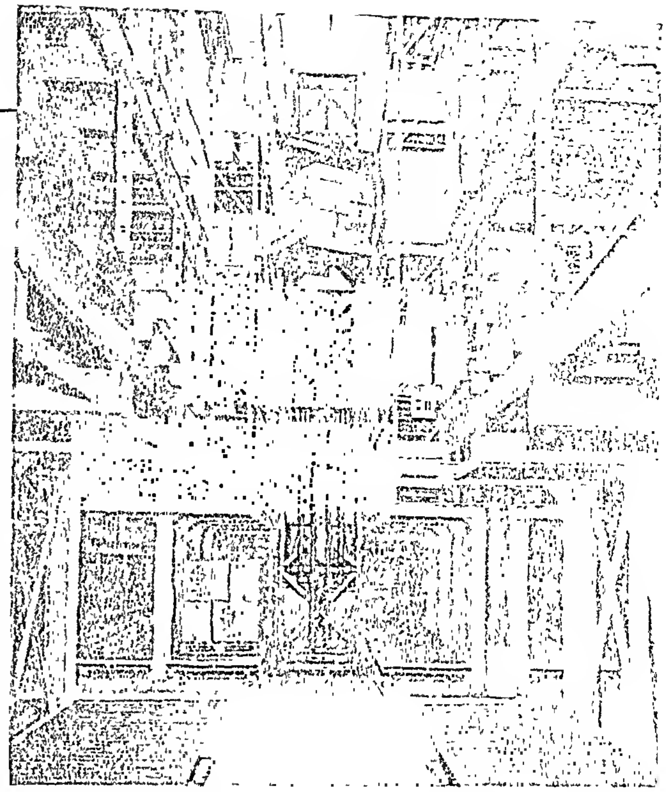
The fork of a typical forklift truck is just in front of the front wheels. These wheels therefore take the load when the truck is operating. To prevent the truck from tipping forward, the load is counterbalanced by a weight at the back of the truck. This weight is carried by the rear wheels. The counterbalancing is achieved by using the principle of a simple lever. Because the fork is much closer to the front wheels than the back of the truck, the load on the fork can be balanced by a much smaller weight at the back.

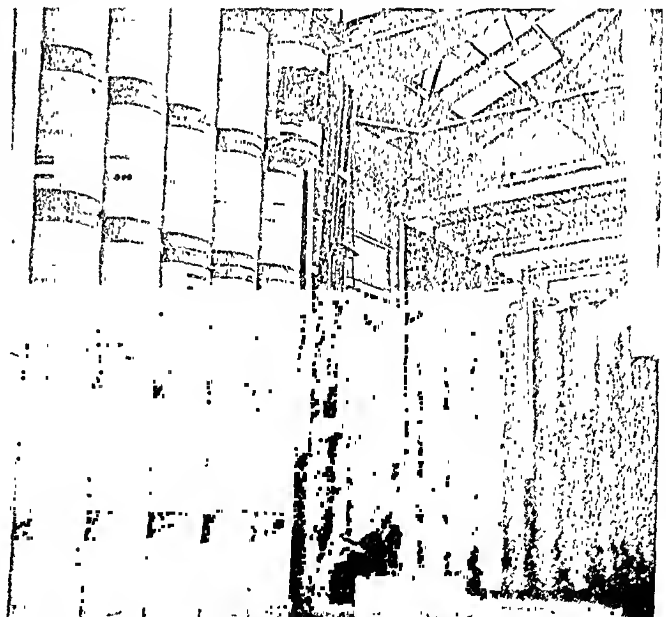
Electrically powered trucks are used in areas where noise and engine fumes would cause problems, such as in small, enclosed warehouses and where food is stored. The power is supplied by heavy batteries. These and the electric motor are situated near the back of the truck and act as the counterweight to the load on the fork. Modern electric forklift trucks have TRANSISTORIZED controls and can operate for 18 hours before their batteries need replacing with fully charged ones.

Forklift trucks with diesel engines are used in large warehouses and open areas. Again, the engine is situated near the back of the truck to act as a counterweight. Such trucks have automatic transmission from the engine to the gearbox and power-assisted steering. Forklift trucks used for outside work often have enclosed cabs.

On most forklift trucks the engine or motor drives the front wheels, which may have solid or pneumatic (air-filled) tires. The rear wheels are used for steering and a forklift truck has a very small turning circle.

The forks are operated HYDRAULICALLY. An electric pump or a pump driven by the engine forces hydraulic fluid through control valves that are operated by the driver. Hydraulic pressure raises the lift jack, which raises the forks by means of a system of chains and rollers. The forks are raised on a mast, which may have double or triple extensions to increase its height. Really





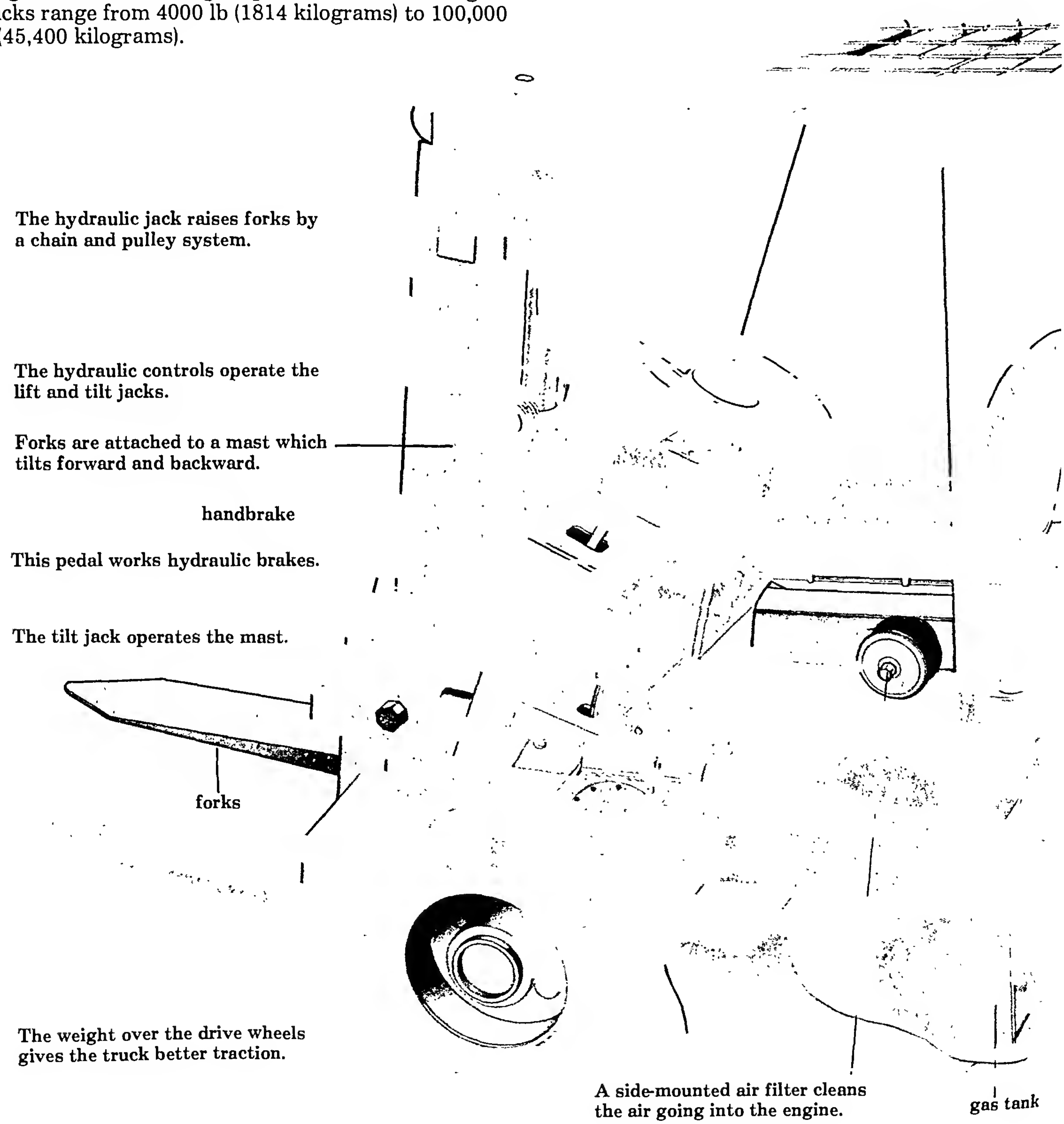
Above, top: A turret truck placing a load onto a high shelf. The truck remains stationary while the load is rotated through 90 degrees to position it accurately on the shelf.

Above: A modern electric forklift truck picking up a bale of paper. The grab can be rotated so that the bale is placed horizontally onto a printing machine.

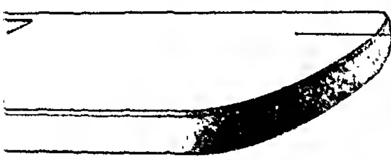
heavy loads can be tilted slightly backward by two hydraulically powered tilt jacks. This moves the center of gravity of the load toward the back of the vehicle, enabling the truck to carry the load without tilting forward. Electric forklift trucks have lifting capacities of between 1000 lb (454 kilograms) and 10,000 lb (4540 kilograms). The lifting capacities of diesel-engine trucks range from 4000 lb (1814 kilograms) to 100,000 lb (45,400 kilograms).

Special purpose trucks

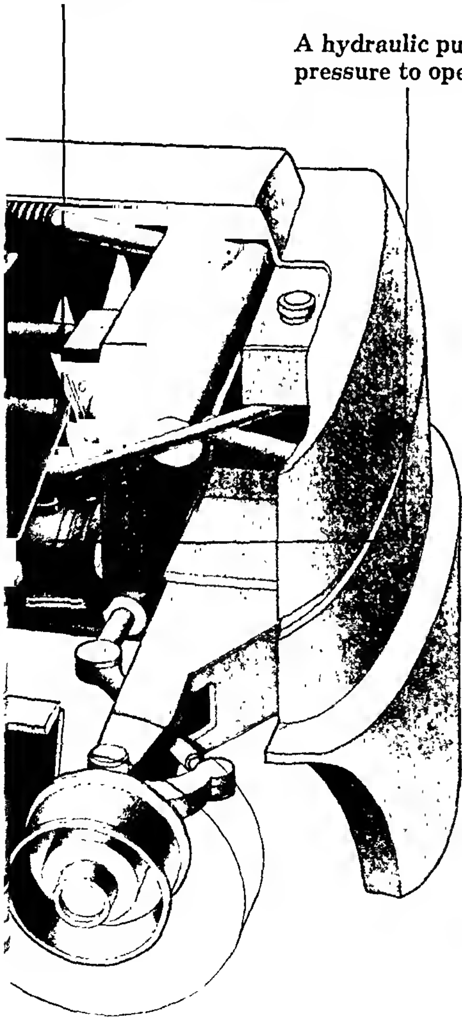
Large storage areas are becoming increasingly expensive and more difficult to find. Thus many industries are now using a form of storage known as high density storage. This simply means that materials are stored not only on the floor area but also in stacks

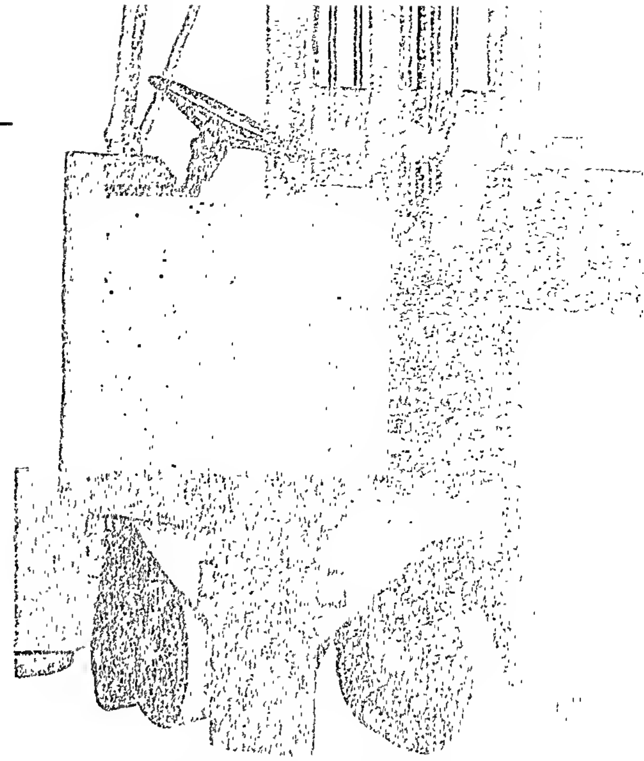


or on platforms that make use of nearly all the space under the warehouse roof. The aisles between storage platforms are very narrow, which increases the storage space still further. To handle goods in this type of warehouse, special trucks have to be used. These are known as reach trucks and turret trucks.



Left: A typical diesel-engine forklift truck. The fork is controlled by the lift and tilt jacks. These in turn are powered hydraulically by an engine-driven pump. The engine, pump and jacks are controlled by levers on the driver's console.





Above: The driver's seat on a turret truck. The controls are transistorized.

A reach truck is one in which the mast and forl move away from the truck body to reach out for a loa The body of the truck is much shorter than a norm forklift truck, but the distance between the front ar rear wheels is about the same. The front wheels a connected to the body by "reach legs" and the ma travels backward and forward along these. Once a loa has been picked up, it is brought back behind the fro wheels. The truck can turn in a very small space and tl driver sits sideways, allowing him to drive the truc comfortably either backward or forward in a narro aisle.

The mast of a turret truck is fixed. However, tl forks are on a "turret" mechanism that allows them t swivel through 180 degrees. This means that the truc does not have to turn and face the load. Instead it ca sit sideways in a very narrow aisle while the fork which can also reach out for a load, are moved to tl required position.

A turret truck can lift loads to a height of 30 feet (meters). Because the driver cannot see exactly whe the fork is at the right height that far above the floo the truck is fitted with a device that allows him t select the required height by pressing a button on th console.

Turret trucks can operate in very narrow aisles—a little as 62 inches (1.6 meters). In such aisles the wheel are guided by tracks. This means that the driver doe not have to steer the truck and can concentrate o operating the turret and fork.

See also: DIESEL ENGINE, ELECTRIC MOTOR

Fossils

Fossils are evidence of ancient life found in rocks. They include dinosaur footprints, animal bones and teeth, and plants turned to stone. The study of fossils, called paleontology, has helped scientists to understand the story of life on earth.

Fossils are common in rocks throughout the world. But these millions of fossils represent only a tiny proportion of the many billions of animals and plants that have lived on earth.

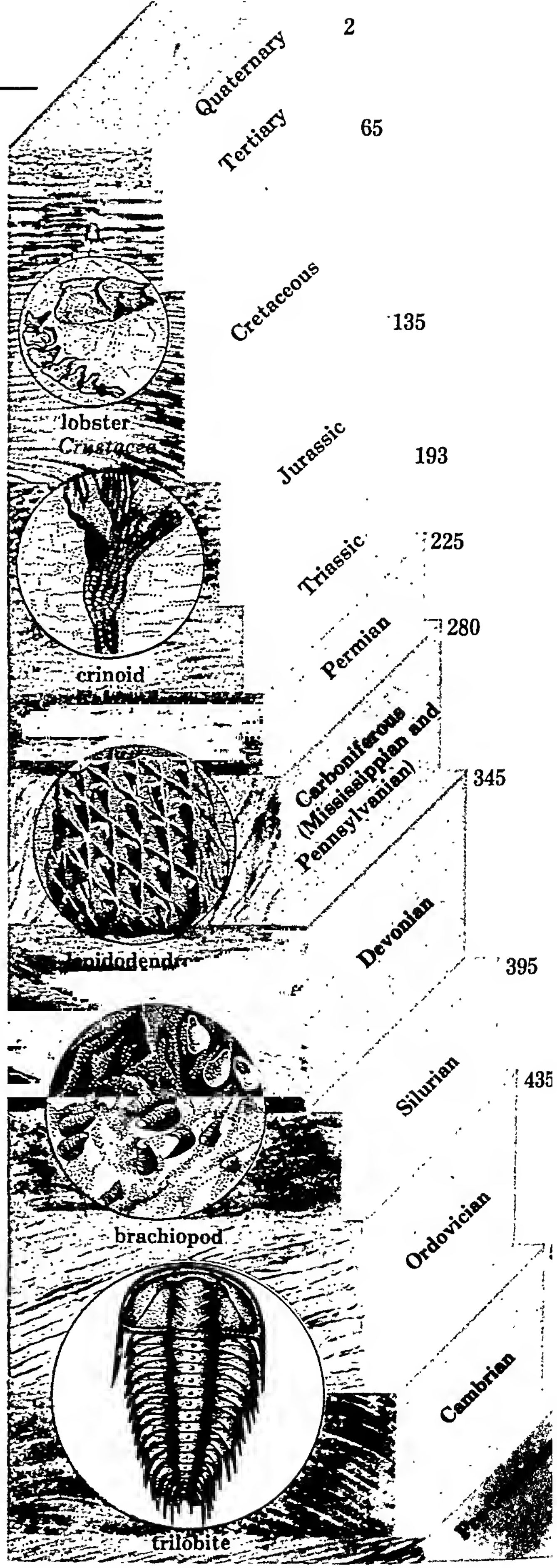
A few fossils consist of the complete bodies of animals. For example, millions of years ago, insects were trapped in the sticky resin that dripped from pine trees. When the resin hardened into a yellowish-brown substance called amber, the insects were perfectly preserved. Even more spectacular are the bodies of woolly mammoths found in Siberia. These animals, which are now EXTINCT, lived during the Ice Age. Their bodies were preserved in frozen soil. Although about 30,000 years old, the bodies were almost in the same condition as when they died.

Such fossils are extremely rare. Complete skeletons are more common. For example, the Rancho La Brea tar pits, in Los Angeles, California, have given up fossil bones of many plant- and meat-eating animals, such as saber-toothed tigers and wolves, and birds, including eagles and vultures. These creatures had drowned in the tar. The flesh on their bodies soon rotted, but their skeletons were preserved.

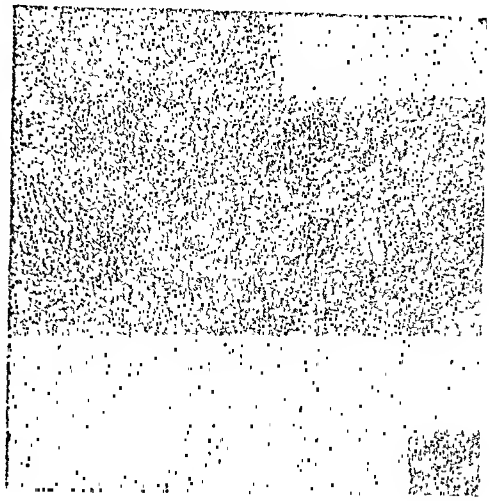
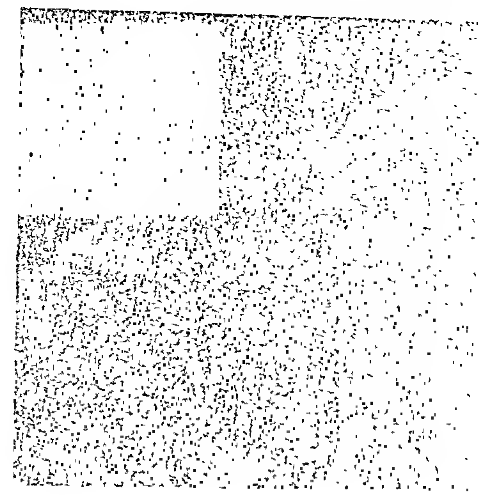
But most fossils contain little or none of the material that formed the original organism. Instead, they have been partly or completely turned to stone.

Molds and casts

The first requirement for a dead animal or plant to be fossilized is fast burial. Left in the air, living organisms quickly decay. Fast burial usually occurs in water—in lakes, rivers, swamps and seas—where sand and mud cover the remains of dead organisms. Some fossils are formed, however, when organisms are buried by sand dunes on land. Even so, the soft parts of organisms decay, leaving only the hard parts. Layer upon layer of sand and mud become pressed together to form rocks, such as sandstones, mudstones and shales. Water seeps through these rocks and often dissolves (wears away) the hard parts of the buried organisms inside them. This produces holes, or molds, in the rocks, which show every detail of the outside of the buried organism.



Right: The geological time scale shows the main periods in earth history, with drawings of some fossils. In the United States, the Carboniferous period is divided into the Mississippian and Pennsylvanian periods.

Above: Fossils are a guide to the age of rocks. Left, trilobites are used to date Cambrian and Ordovician rocks. Brachiopods (shellfish), center, were abundant between the Ordovician and Permian periods. The ammonite fossils, right, date from the Jurassic period.

Such molds are often filled by other minerals. A rock cast is then formed. The fossil ammonites shown on this page are casts. The mineral that has filled the molds to form these casts is iron pyrites, or fools' gold.

Petrified fossils

Fossil molds and casts contain nothing of the original organism. But many fossils are only partly petrified (turned to stone). For example, when shells are buried, minerals are deposited by water in the pores in the shells. These fossils look the same as the original shells, although they are much heavier. Bones are also petrified in the same way.

When a shell, bone or another part of an organism is buried for a long time, it may be completely petrified. In some fossils, such minerals are calcite, silica and pyrite replace every cell. Geologists call this process REPLACEMENT. For example, ancient logs are turned to stone. Petrified logs contain every detail of the wood, including the annual rings that indicate a year or a season's growth. The Petrified Forest National Park, Arizona, contains many petrified logs. These logs are made of multi-colored minerals, including some semiprecious ones. The logs are the remains of a swampy forest that grew about 200 million years ago. The logs were fossilized when they were buried by mud, sand and volcanic ash.

Other kinds of fossils

Leaves of plants may be preserved as carbon smears. These thin films of carbon found on rock surfaces show the exact shape of the leaf. Coal, which consists mostly of carbon, was formed from plant remains and is called a fossil fuel. Coal layers often contain beautiful plant fossils.

Some fossils are called trace fossils. These include petrified eggs, animal droppings, burrows and footprints formed in mud. Such fossils give us information about the ways of life of animals.

Where to find fossils

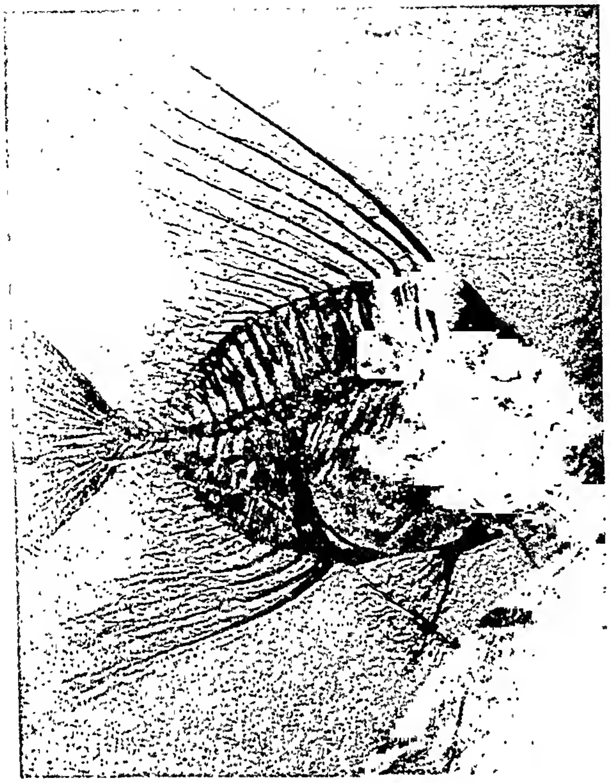
Fossils of ancient sea creatures have been found near the tops of the world's highest mountains, such as Mount Everest. The rocks in which the fossils were formed are sedimentary rocks. These consist of sediments, such as sand and mud or the remains of once-living things. But these rocks have been squeezed up into mountain ranges.

Most fossils are found in sedimentary rocks. Igneous rocks, formed when molten rock hardens, seldom contain fossils because they burn everything with which they come into contact. Besides sedimentary and igneous rocks, there are also some rocks called metamorphic rocks. These rocks include sedimentary rocks which have been changed by great heat, pressure and chemical action.

For example, marble is a metamorphic rock which was originally limestone. It may contain fossils, but such fossils are usually DISTORTED by the heat and pressure. The best place to look for fossils is, therefore, in sedimentary rocks, which cover three-fourths of the earth's land area.

The importance of fossils

People once thought that fossils were the remains of animals drowned in Noah's Flood, which is described in the Bible. But people who study fossils (paleontologists) now realize that they are clues to the evolution of life on earth.



Left: This fossil of a bony fish was found in Italy. It dates from the Eocene epoch, the second epoch in the Tertiary period. This epoch began 55 million years ago and ended 40 million years ago.

Right: These fossilized tree trunks in Arizona are more than 200 million years old. Each cell in the trunks has been replaced by minerals, so that every detail of the original wood has been preserved.

The oldest known fossil is about 3100 million years old. It was formed by simple plants called blue-green algae and it was found in Zimbabwe, in southern Africa. But fossils are generally rare in rocks formed before the start of the geological time called the Cambrian period, which began 570 million years ago.

The reason why Cambrian rocks are rich in fossils, while Precambrian period rocks contain very few fossils, is still not fully understood. Many paleontologists believe that Precambrian life forms were all made of soft material, while many organisms at the start of the Cambrian period contained hard parts.

Index fossils

Trilobites were common animals in the Cambrian and Ordovician periods. These animals resembled wood lice, but they lived on the sea bed. Fossil trilobites, which preserve the shapes of the hard parts of these animals, are shown on the previous pages. The shapes of these trilobites are different because there were many species (kinds) of these animals. Each species had its own distinctive shape. Some trilobite species lived only a fairly short time on earth before they became extinct (died out). Hence, if two layers of rock, even if they are many miles apart, contain the same kinds of short-lived trilobite fossils, they must be of the same age. Fossils, such as trilobites, which help us to date rocks are called ZONE or index fossils. From a study of these fossils, geologists worked out the RELATIVE ages of rocks—that is, they could tell whether one rock layer was older or younger than another. Other index fossils are used to date rocks formed in other periods.

From the study of index fossils, geologists divided the last 570 million years of earth history into three long eras: the Paleozoic ("ancient life") era, between 570 and 225 million years ago; the Mesozoic ("middle life") era, between 225 and 65 million years ago; and the Cenozoic ("recent life") era, which spans the last 65 million years. Each of these eras is divided into periods, which are shown in the geological time scale. Fossils enabled geologists to work out the relative ages of rocks. However, it was not until after the discovery of RADIOACTIVITY in the early 20th century that the absolute ages of the periods could be measured.

Fossils and evolution

The study of fossils helped the British naturalist Charles Darwin (1809–82) to work out the theory of evolution. According to this theory, all living things on earth are descended from earlier and simpler ancestors. For example, Darwin believed that MAMMALS, whose fossils first appear in rocks formed during the Triassic period, gradually evolved from REPTILES. In turn, reptiles, whose fossils first appear in rocks formed in the Pennsylvanian (Upper Carboniferous) period, evolved from AMPHIBIANS. Amphibians evolved from bony fishes with lungs, and those evolved from primitive armored fishes, fragments of which have been found in rocks of the late Cambrian period.

However, many questions remain unanswered. First,

because the fossil record is incomplete, many of the intermediate types between major groups have not yet been found. The study of fossils also suggests that evolution was not always gradual, as Darwin suggested. At times, there have been sudden bursts of development. For example, there was a sudden increase in the number of life forms at the start of the Cambrian period.

Mass extinctions also occurred. Particularly spectacular was the disappearance of the giant reptiles, including the dinosaurs, at the end of the Cretaceous period 65 million years ago. Sudden changes may result from variations in climate.

While seeking answers as to their disappearance, paleontologists continue to learn through fossils how the dinosaurs lived. Fossilized nests, thought to be about 73 million years old, have been found with eggs containing dinosaur embryos. Study of some by a CAT scanner showed leg joints fully developed. This probably means that type of dinosaur matured rapidly and could move and find food soon after hatching.

Unusual discoveries

Scientists have found the first amphibian encased in amber (hardened resin of pine trees)—a 40-million-year-old frog—in a mine in the Dominican Republic. Also, samples of prehistoric atmosphere were recovered from crushed Canadian amber dating from millions of years ago. Analysis showed that it had ten percent more oxygen than does our modern atmosphere.

See also: **EVOLUTION, MINERALS, RADIOACTIVITY**

Below: The feather marks in this fossil of *Archaeopteryx* show that it was a bird.

Bottom: A geologist covers a dinosaur skull in paper and sacking soaked in plaster of Paris. When this has hardened, the fossil can be safely moved.

Below right: The Dinosaur National Monument, Utah, contains many huge dinosaur bones embedded in a vertical rock face.

Fountain Pen

People have written with some form of ink and pen since ancient times. The fountain pen, which came into popular use in the late 19th century, made writing with ink better and easier. It did away with constantly dipping a point in the fluid.

The fountain pen is so called because the supply of ink in it is kept in a reservoir, or fountain. This reservoir is a tube inside a CYLINDRICAL container of plastic or metal. The ink from it flows onto a nib, which is made of stainless steel or gold and has a thin slit in its point. A feeder device at the open end of the tube controls the flow of ink. A screw-on or press-on cap protects the nib and also keeps it from accidental leakage.

The action of a fountain pen relies on the elastic-like force in the surface of a fluid, called surface tension. Surface tension has the unusual effect of causing liquids in a narrow tube to rise against the force of gravity. The ink in the pen's reservoir clings to the tube's walls until some ink leaves the open end—then it flows. Surface tension of the ink makes it flow down onto the nib to the slit and keeps the ink from running off the nib. When the nib is pressed against paper in the act of writing, the slit widens and releases the ink.

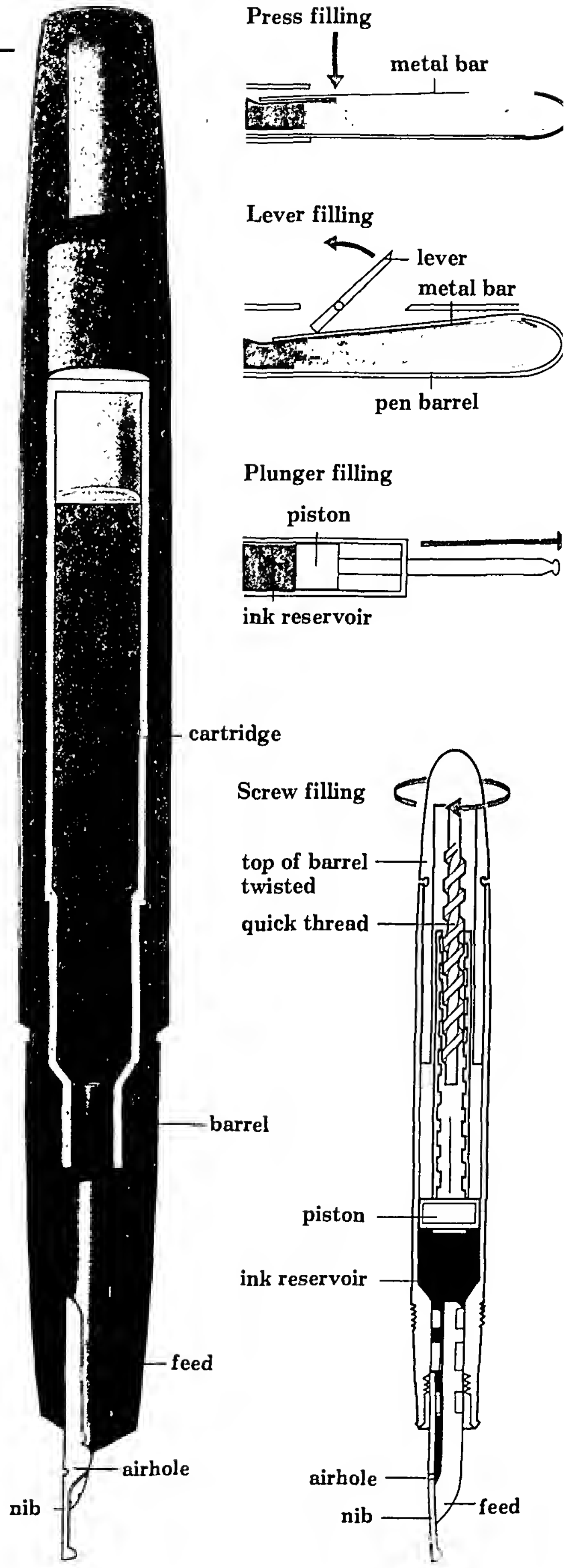
Fountain pens have different mechanisms for being loaded with ink. One type has a reservoir made of an elastic material, with a lever on the outside. With the lever pulled out to compress the tube, the tip of the pen is inserted into ink. When the lever is released, the tube fills with ink. Another type draws in the ink with a plunger used as a suction device. A third gets its ink from a cartridge. A cartridge is a replaceable plastic container of ink, which is the actual reservoir itself. It is put in by unscrewing apart the body of the pen. When the body is screwed together again, the lower end of the cartridge is automatically opened up.

There is usually an air hole on the outside to allow air to flow into the reservoir behind the ink. This equalizes the air pressure so that the ink can flow.

Nibs come with tips of various widths so that people can choose the style of stroke they like best, from a very fine line to a very heavy one.

The first fountain pens were produced in Britain around the 1830s, but they used a plunger that had to be worked repeatedly to keep ink flowing. The basic fountain pen as we know it today was introduced by the inventor L. E. Waterman in the United States in 1884.

See also: BALLPOINT PEN, GRAVITY, INKS, SURFACE TENSION



Right: A cross section of a cartridge pen (in red and blue) and some examples of filling methods of other types of fountain pens (small sketches).

Frame Construction

The tents used by the American Indians are an early example of frame construction. The rigid framework holding up the animal skins was made of wooden poles. Today, the frameworks of all kinds of machines and buildings are usually made of strong metals.

The family car, the passenger airplane, the cargo ship, the house, the bridge, the skyscraper—all of these machines and structures are important in modern life. All of them seem very different, but they have one thing in common—they are built on a frame construction. This inner framework is not always easy to spot, especially in the smooth metal surfaces of cars and planes, but it is there. In fact, it is the frame which gives the shape to anything of which it is a part.

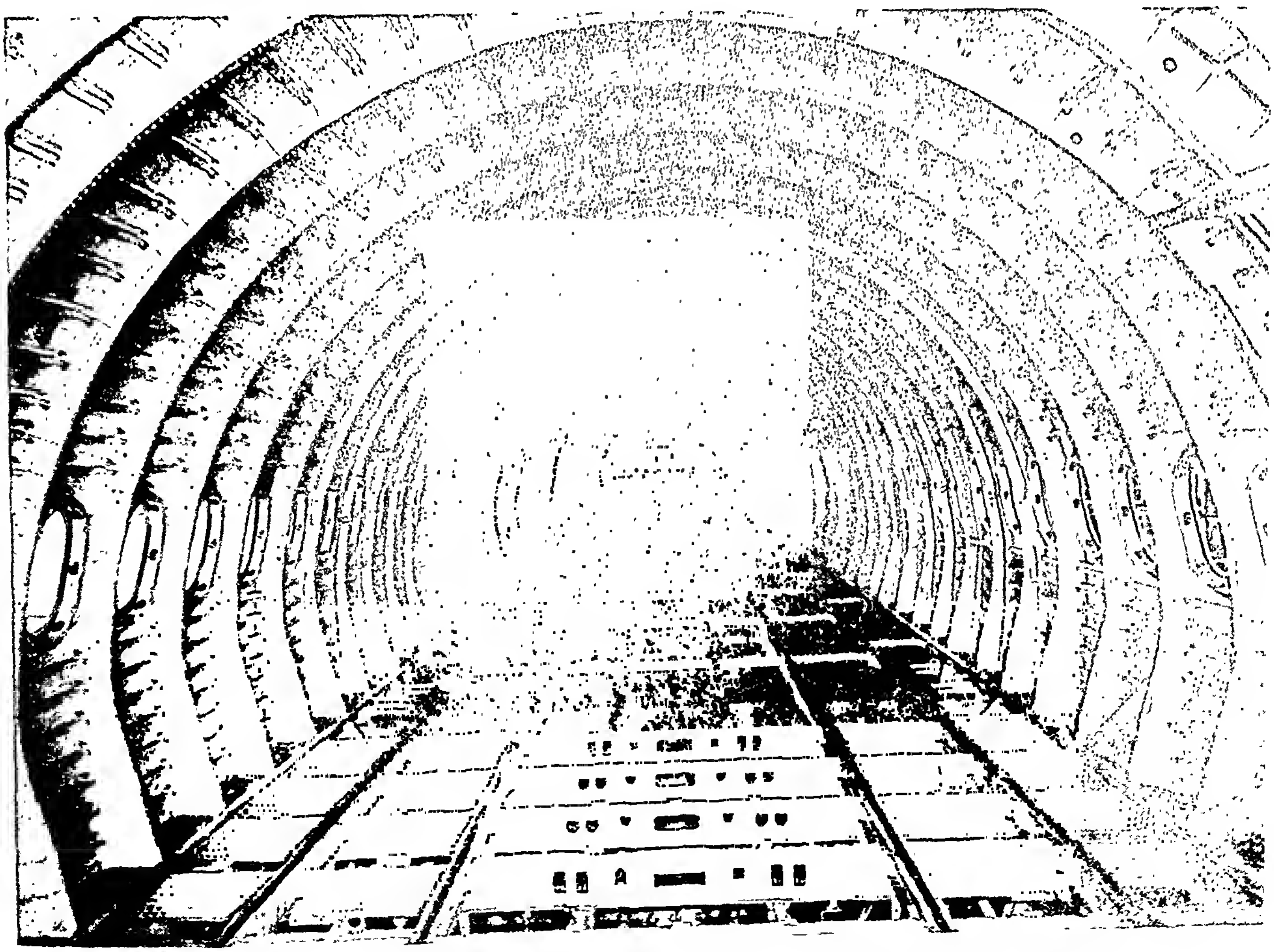
The idea of frame construction is very old, as the tents and small boats used by people in ancient times show. The importance of the framework to a tent is easy to see today because if the poles were not there, the covering would fall in a heap. The covering, which forms the outside shell, has no shape at all without the framework underneath.

The frame at work

A frame is a structure that can carry a load. The human skeleton is a frame that holds the body together and allows movement through the joints. In fact, the framework is sometimes called the skeleton. Frames have pin joints, which rotate, or stiff joints, which keep the whole structure more rigid.

Frames have a covering called a skin. This covering is no longer made of real animal skins, as in the tents of old, but of concrete or metal. The most widely used

Below: *This inside view of an airplane shows the framework clearly. It is a complicated structure. The frame is of metal, usually aluminum, and it gives the plane its rounded shape. The outer shell, or skin, of an airplane is built onto the frame in such a way as to make the whole structure stronger.*



metals for this purpose today are steel and aluminum.

Timber frames are still very often used for houses. They are usually made of rectangular wooden slats and are connected by nails or bolts. The parts used for metal frames can be hollow tubes, either round or rectangular, or solid ones.

Buildings and bridges

People have been building houses for thousands of years, and they have used frame construction from the beginning. The one-room, hand-built log cabin that Abraham Lincoln was born in had a frame. The huge Empire State Building, which was the tallest building in the world until the 1970s, also has a frame construction.

Concrete is the material most used for building frameworks today. Reinforced concrete is made by putting steel bars inside each concrete beam. This makes them much stronger. Pre-stressed concrete has wire that has been stretched very tight inside each beam. Pre-stressed beams bow upward when there is no load on top and lie straight when extra weight is added. This keeps them from cracking or breaking.

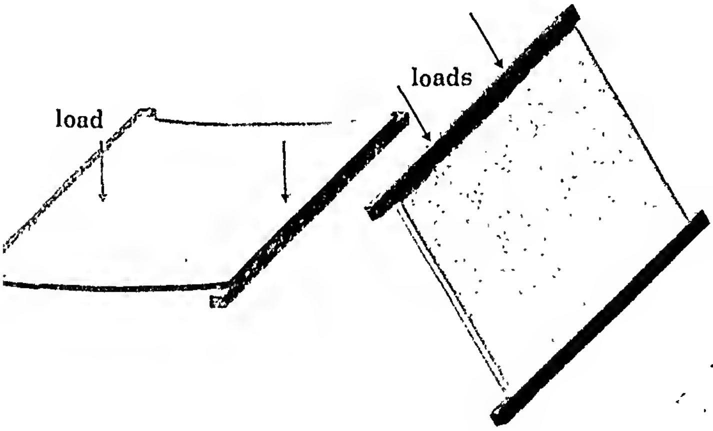
Steel beams, or girders, can be made in many sizes and shapes. They are joined together with bolts or by welding. A welded joint is made by heating two pieces of metal with a welding rod. The metal in the rod melts before the other two, and flows around the area to be joined. It forms a strong bond when it cools. The girders are made into a frame in the same way that you would use a construction kit.

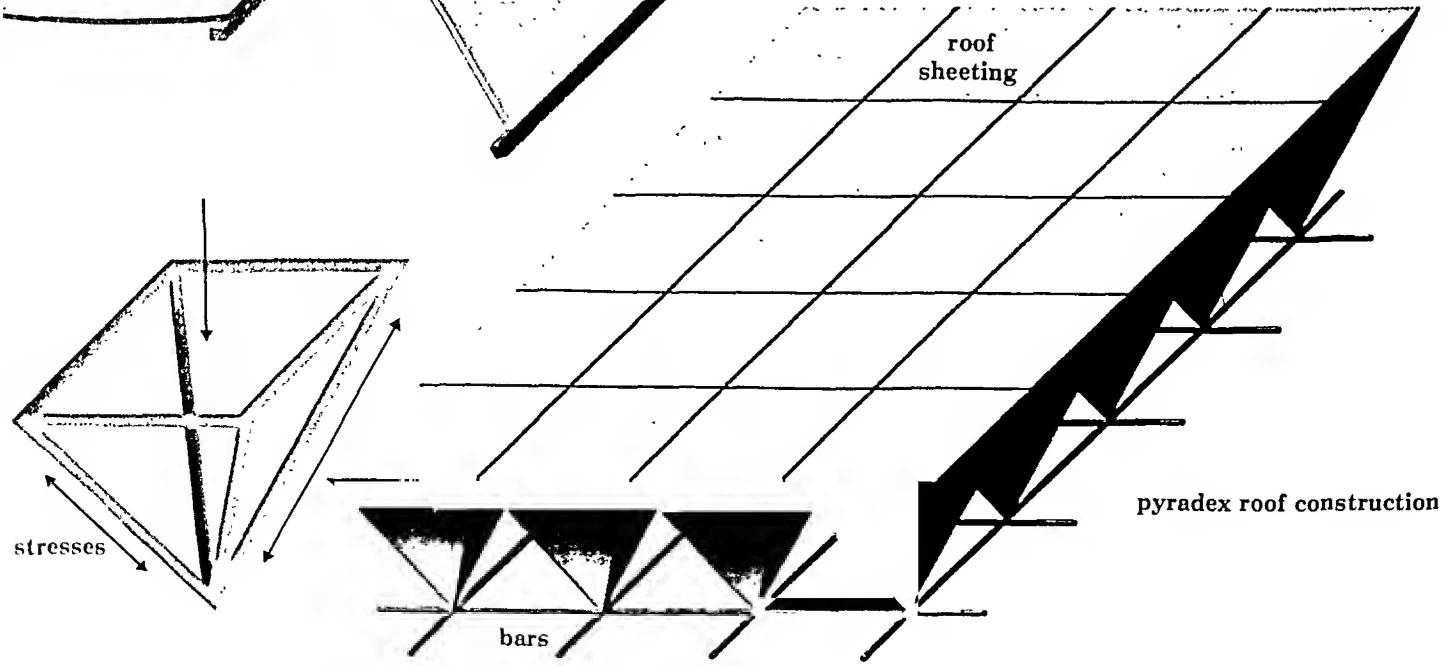
Each floor of a tall building is made up of a steel frame that is covered by some kind of flooring. When all the floors have been built, the whole frame is covered on the outside. Most modern buildings for commercial use, such as offices and hotels, use glass, stone or metal of some kind. Private homes are more often covered with brick or wood.

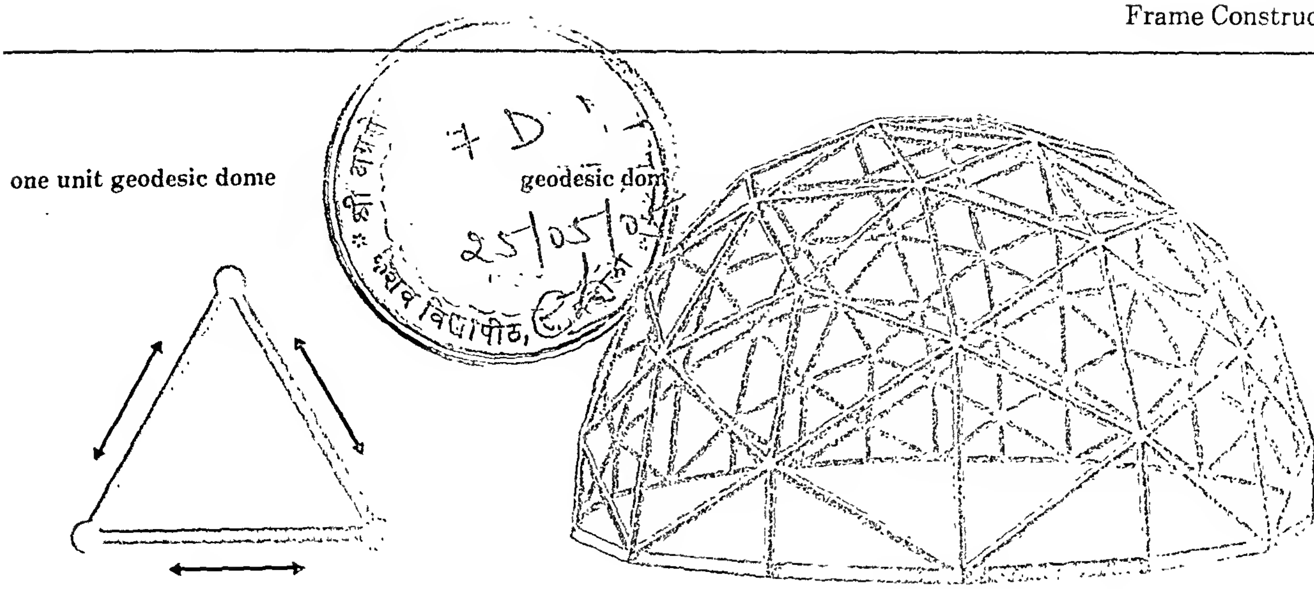
Long bridges are examples of frame construction in civil engineering. Some famous ones are the New River Gorge Bridge in West Virginia, the Quebec Railway Bridge in Canada, the Humber Bridge in England, and the Rio Niteroi Bridge in Brazil. Large bridges and buildings became possible only after steel began to be used for frames.

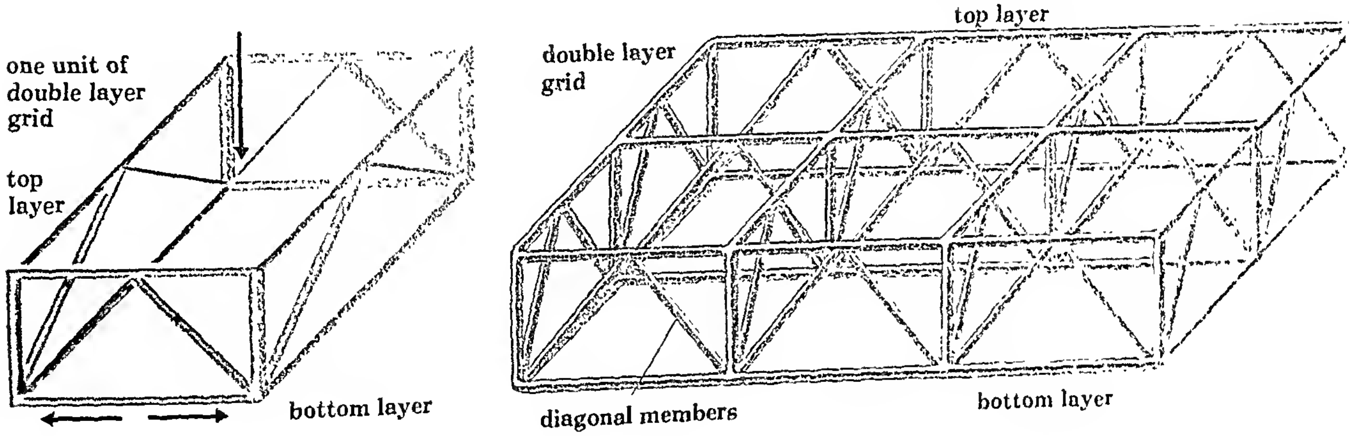
Sections of metal and concrete frames are bolted, riveted or welded together on the site where a bridge or building is being put up. Frame construction is also a

Below: The frame of a roof built on the principle of the stressed skin. Aluminum sheets are welded together at the edges to form a pyramid, or triangle, shape. These pyramids are connected together with their tips resting on a supporting frame. This kind of construction carries a load more on the ends than on the top (the stressed skin rule), and is stronger.









Above: A geodesic dome roof. Many triangles of material, usually metal, are built up to form a half circle. This frame is one of the strongest that can be built and requires only a light skin, such as plastic or aluminum. The entire roof, even very big ones, can be held up by only one pillar at each "corner."

great help in assembling the prefabricated (made beforehand) sections of a building.

Cars and planes

The frames for cars and planes are made of metal. Only about 70 years ago, airplane frames were made of wood and these frames were covered with fabric. Today's large planes are made entirely of metal. They are constructed in such a way that the frame and skin add strength to each other. Light aircraft and small private planes are still built with fabric skins over an aluminum alloy frame. In heavier planes, the frame is made stronger by stiffening it with ribs.

Cars used to have a separate frame, called a chassis. The body of the car was bolted onto this metal frame. Most cars today have a one-piece construction that is like a complete steel shell.

Boats and ships

Frame construction for river and sea craft has a very long history. The coracle, a canoe-like boat, was made with animal skins stretched over a thin wooden frame. It is known to have been in use from the earliest times, and is still used in parts of Great Britain today. Traces of ancient coracles have been found everywhere in the world except Australia and Africa. The modern sporting canoe is often constructed in a way similar to this early water craft.

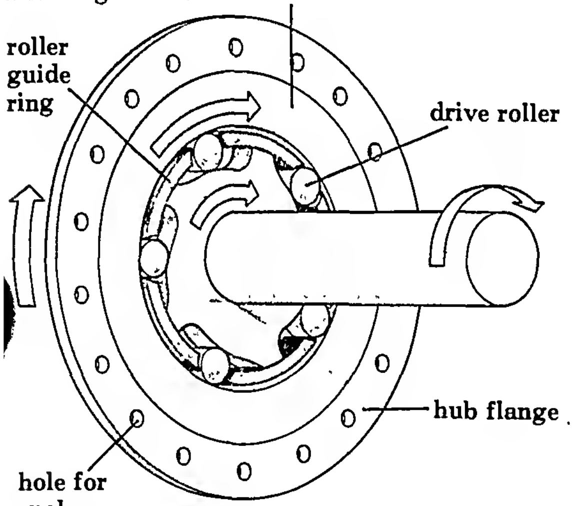
Modern ships have a covering of steel plating over the framework. This plating makes the ship more watertight, as well as stronger. In building a ship, many rigid steel frames are welded together. Then these are spaced about 24 inches (60 centimeters) apart to form the hull. The steel plating is attached to the skeleton.

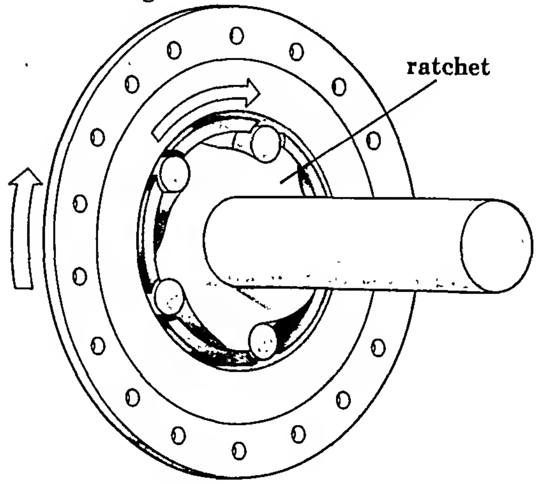
See also: BUILDING TECHNIQUES, CONCRETE

Freewheel

The freewheeling bicycle hub allows us to pedal and give driving power to the rear wheel, and when we stop pedaling, the bicycle freewheels. This kind of system is used in machines of many types.

The bicycle freewheel is really an adaptation of the simple ratchet and pawl device, which is of great importance in the transmission of power. The ratchet is a wheel with teeth. Each tooth has one side much longer than the other so that the teeth appear to lean in one direction. The pawl is a pointed lever that is held against the ratchet by a spring. When the wheel with the ratchet is turned in one direction, the pawl engages a tooth and either stops the wheel turning or allows power to be transmitted through it. If the wheel is turned in the other direction or is stationary the pawl slips over the ratchet teeth with a clicking noise.





The bicycle freewheel

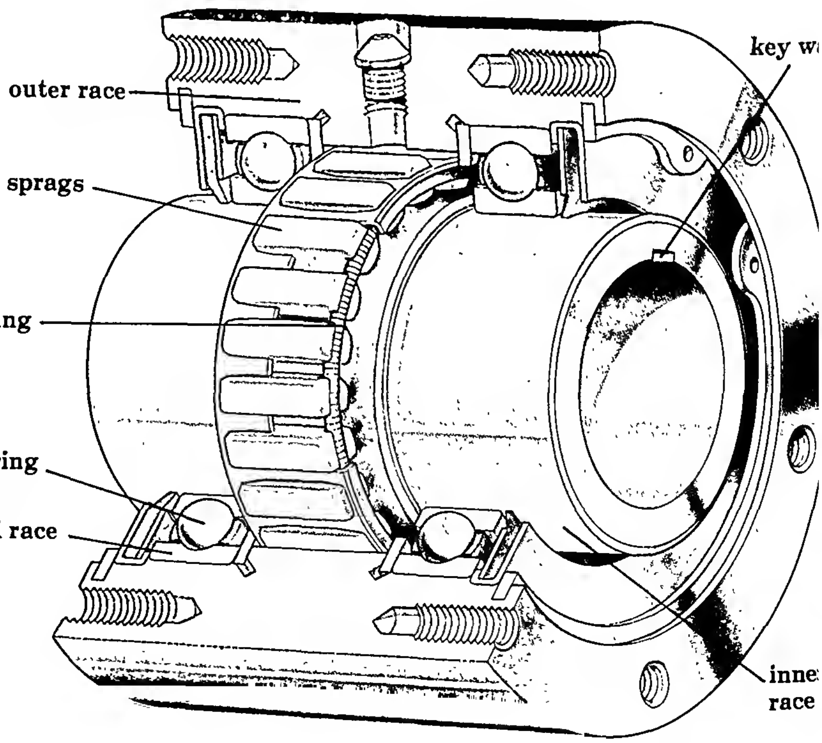
In the bicycle freewheel system, the pawl is replaced by a set of roller bearings in a guide ring. In the "forward" position, when the pedals are pushed forward, the rollers are jammed against an outer sleeve because of the shape of the ratchet. The power is sent through the rollers to the sleeve, which is fixed to the rear wheel of the bicycle, and so drives it around.

When freewheeling, the rollers fall into depressions in the surface of the ratchet and are no longer jammed against the sleeve. The sleeve can therefore go aroun freely (see diagram).

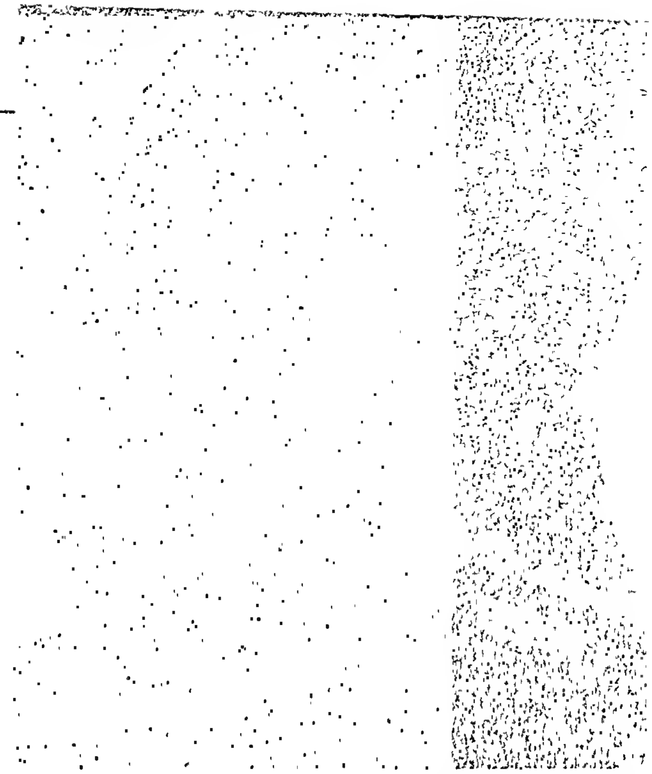
See also: BICYCLES, GEARS

Left: The top diagram shows a bicycle freewheel in the pedaling position. The roller bearings are jamme against the hub sleeve. In the bottom diagram, the rollers are in depressions in the ratchet. The bicycle freewheels.

Below: A freewheel clutch that is used in all kinds of machines, from small home electrical machines to oil drilling rigs. Steel wedges called sprags are placed between the inner and outer races. If the inner race i turned counterclockwise, the clutch freewheels. If it i turned in the other direction, the sprags are tilted and the two races lock together. Power can then be transmitted from one to the other.



Friction



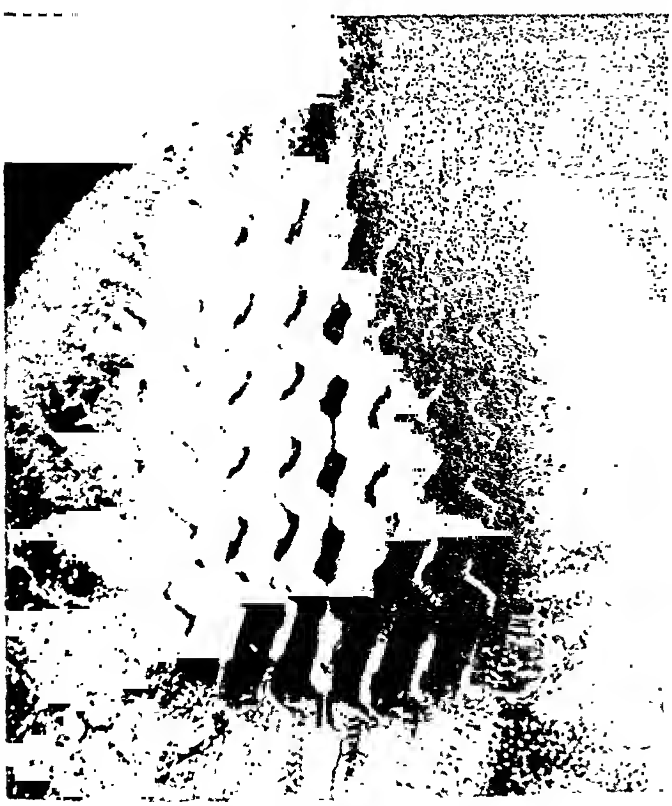
Above: A disk brake under test glows red hot. Brake use surface friction to a useful end. They turn energy of motion into heat and slow us down.

Without friction the world would be a strange place. We could not walk because our feet would be unable to grip the ground. Any form of transport that runs on wheels could not move because the wheels would simply spin around. Even a nail driven into a piece of wood would not grip if there was no friction between the nail and the wood.

Friction occurs when any two objects move against each other. There are two kinds of friction: "sliding friction" and "rolling friction." Sliding friction occurs when two surfaces slide over each other, as when a box slides across a table. Rolling friction happens when a rolling body moves over a surface. For example, when an automobile tire moves along a road there is rolling friction between the tire and the road.

The ever-present resistance of friction is caused by the unevenness of all surfaces. The smoother the surface, the less the friction. But even the surface of a piece of highly polished steel, looked at through a microscope, is really a surface of hills and valleys. Even a sheet of ice has its ups and downs.

Friction depends on the pressure between an object and the surface it is rubbing against. In other words, the heavier an object is the more difficult it is to slide it along a surface. A sled slides along the snow with friction between the runners and the snow. The mor people sitting on the sled, the harder it is to pull along The increased weight creates more friction.



Left: Treads on tires increase friction between the automobile and the road. This gives a better, and therefore safer, grip.

Cutting down friction

There are a number of ways of reducing friction. Th friction between wheels and their axles can be cut dow by putting a film of oil between them. Ball bearings o roller bearings can be placed between the wheel and th axle. The smoothness of the steel balls or rollers allow the wheel to turn freely with less friction.

Friction can be useful

When you apply the brakes on a bicycle or a car you ar using friction. It is friction between the brake pads an the wheel that brings us to a stop.

When we strike a match, it is friction between th match and the box that creates the heat that IGNITE the match.

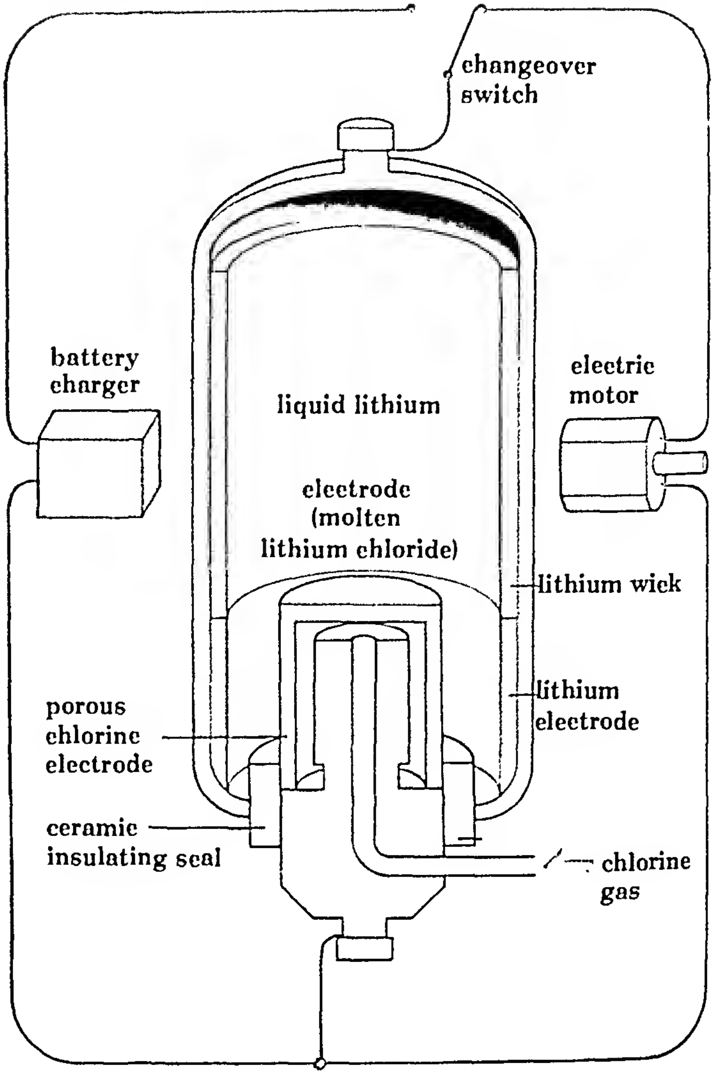
Everything that moves on earth is subject to friction It is only in space that virtually nothing exists t produce friction. With no air to slow them up spacecraft may continue to travel almost foreve without using any power.

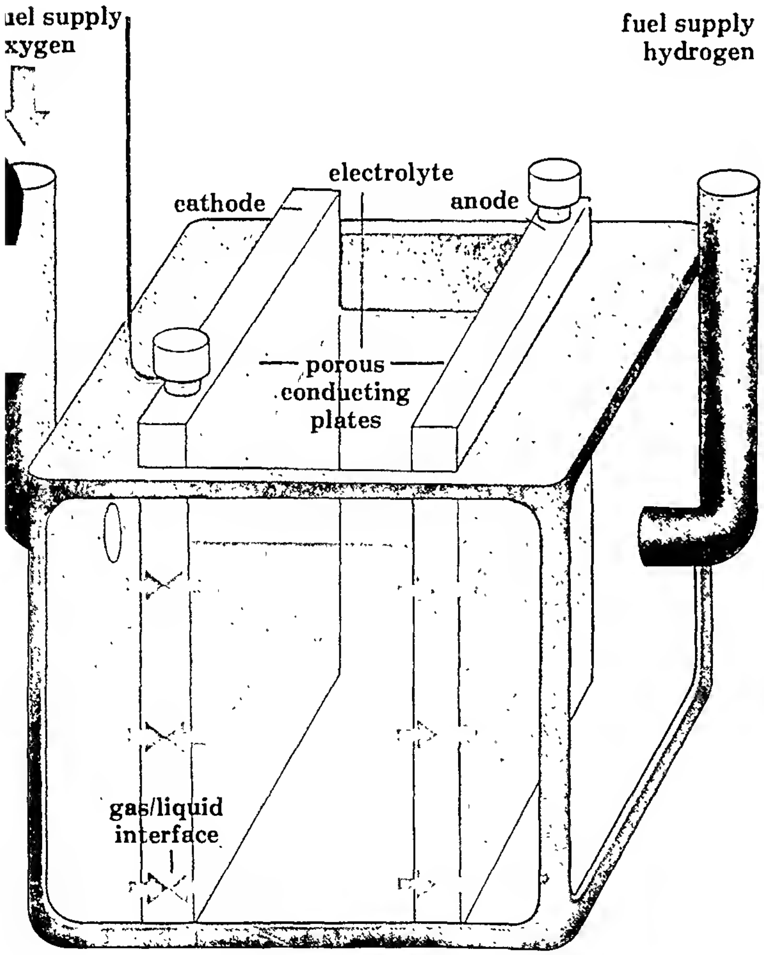
See also: BEARINGS, BRAKES

Fuel Cell

The fuel cell is a device used to generate electricity. This is done by converting the energy that is given off in a chemical reaction into electrical energy. Automobile storage batteries and dry cells get electricity from chemical reactions, but will run down after a while. In a fuel cell, the chemicals that make the electricity are fed in all the time and will not run down.

Fuel cells work by the combination of gases such as hydrogen and oxygen. These gases do not have to be supplied to the cell in pure form. A fuel cell can work with fuels such as natural gas, gasoline or kerosene, all of which contain hydrogen. The oxygen is often obtained directly from the air. A chemical reaction between hydrogen and oxygen is called OXIDATION, with the oxygen called the oxidizer. Hydrogen and oxygen combine to form water, which may be removed from the cell by EVAPORATION. So long as the fuel and the oxidizer are fed into the cell and the water is removed, the cell will generate an electric current.





Above and left: Two types of fuel cell. In the hydrogen–oxygen cell on the left, the gases react with the liquid electrolyte, forming water and releasing electrical energy. The lithium–chloride cell above combines chlorine with lithium to produce lithium chloride and electrical energy. When the cell is recharged, the lithium chloride separates into lithium and chlorine again, ready for re-use.

The story of the fuel cell

In the 1930s, a young English engineer, Francis Bacon, began to work on a gas battery. In 1959, he demonstrated a hydrogen–oxygen battery producing 6 kilowatts of power. This "Bacon cell" was taken up in the United States and developed by Pratt & Whitney Aircraft who used the cell as a source of electricity on board the command module of the Apollo spacecraft. More recently, Pratt & Whitney have been working on fuel cells that can be fed with ordinary fuels such as natural gas and fuel oil, using air as the oxidizer.

How it works

The principle of the fuel cell is the same as that of the primary battery, except that the functions of the electrodes are separated from those of the REACTANTS.

Two electrically conducting porous plates are fixed

next to each other. The space between them is filled with a liquid electrolyte. An electrolyte is a liquid that carries an electric current between two electrodes.

The liquid electrolyte seeps into the electrodes, but is prevented from passing right through them. On the outside of one electrode is hydrogen gas, and on the outside of the other is oxygen. Each gas goes part-way into its electrode but cannot pass right through because of the electrolyte. Just a little of each gas DISSOLVES in the electrolyte and reaches the wet surface of the electrode on its side of the cell. So, the surface of one electrode becomes covered with a very thin layer of hydrogen and the surface of the other with oxygen.

When the oxygen enters the electrolyte, it combines with water to form electrified particles. The particles pass through the electrolyte to the other plate. There they combine with hydrogen to form water. In this reaction, electrons are given up to the plate. The plate through which hydrogen passes is therefore negatively charged since it has an extra supply of electrons. These electrons flow through a wire to the other plate, which, being short of electrons, is positive.

The current will continue to flow as long as hydrogen and oxygen are supplied to the cell. The potassium hydroxide liquid electrolyte which gives a path between the two plates, does not change.

But the water formed in the reaction must be removed. If it is not, it waters down the electrolyte and cuts down the efficiency of the cell. The Apollo astronauts used such water for drinking.

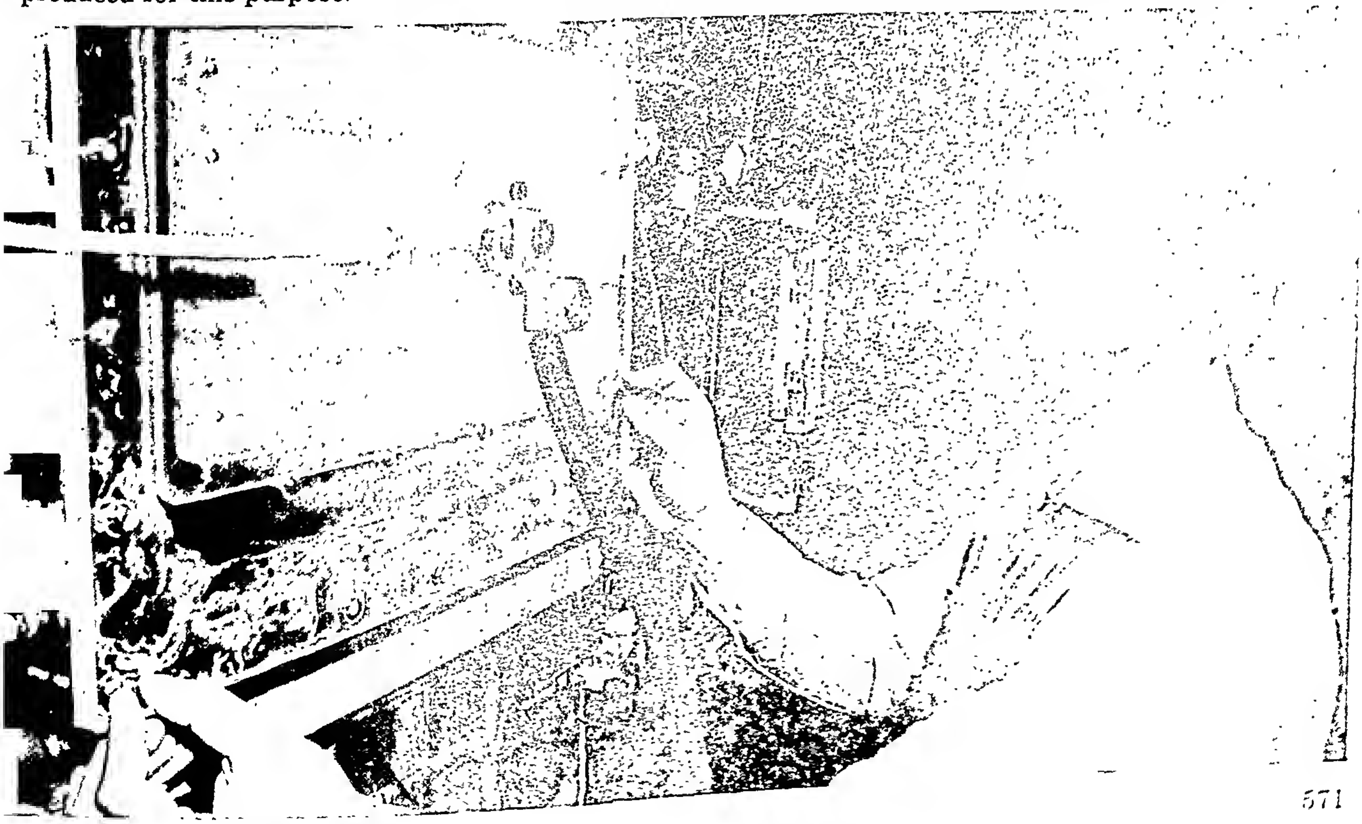
The main advantage of fuel cells over other ways of generating electricity is their high efficiency. Nearly all our electricity comes from generators that use heat The efficiency of any machine that uses heat is limited. In theory, fuel cells can change chemical energy into electricity without any increase in temperature. But in practice all fuel cells designed so far produce some heat

The use of fuel cells

At present, fuel cells are used to power some military equipment and spacecraft electronic systems. But they are too costly for general use. Scientists are trying to produce a cheap and efficient cell that will run on cheap fuel. Much effort has gone into producing a fuel cell that can power electric cars, but no cell has yet been made that gives enough electricity in relation to its weight. However, there can be little doubt that the fuel cell is a source of electricity for the future.

See also: BATTERY, ELECTRICITY, ELECTRIC VEHICLES, GENERATOR, OXIDATION

Below: An aluminum-air fuel cell being developed for use as a rechargeable energy source for electric road vehicles. So far, no fully satisfactory cell has been produced for this purpose.



Fuel Injection

Diesel and gasoline engines burn a mixture of fuel and air. In most gasoline engines, the fuel and air are mixed before they enter the engine. In all diesel engines, and now in many gasoline engines, the fuel is injected separately into the engine.

Fuel injection has always been used on diesel engines, but the first commercial design was probably the one invented by Robert Bosch in about 1912. Then in the 1930s, fuel injection systems were developed for use in airplane gasoline engines. During World War II, many airplanes were fitted with some form of fuel injection. These systems proved so successful that engineers developed fuel injection units for racing cars. In 1957 fuel injection came into use for American passenger automobiles.

Diesel injection

Diesel engines require a supply of fuel at high pressure, which is what the fuel-injection system can do. The system also means that the fuel is injected in the required quantity, and at the right moment. A complete fuel-injection system is made up of fuel filters, injector nozzles, a high-pressure metering injection pump and a low-pressure fuel lift pump. This pump sends fuel from the tank into the injection system.

The main part of the diesel fuel injection system is the injection pump. There are two main types: the in-line multi-cylinder pump and the distributor pump. Both are driven by the engine.

In-line pump

The in-line pump has a separate pumping element for each cylinder of the engine. Each element consists of a plunger inside a barrel. When the plunger is down, fuel enters at the top of the barrel. In some cases, the fuel simply flows down from an overhead tank.

A cam turned by the engine operates the plunger. As the plunger rises, it closes off the inlet and forces the fuel through a non-return valve to an injector. Each cylinder has an injector (a spring-loaded valve). This valve is forced open by the pressure of the fuel, which sprays in a fine jet into the combustion chamber of the engine. Once the jet of fuel has entered the cylinder, the pressure falls and the valve closes. In engines with several cylinders and pumping elements, a series of cams is used to operate each plunger in turn.

Control over the amount of fuel delivered is called metering. The distance that the plungers travel controls the amount of fuel delivered, which means a much more efficient system.

Distributor pump

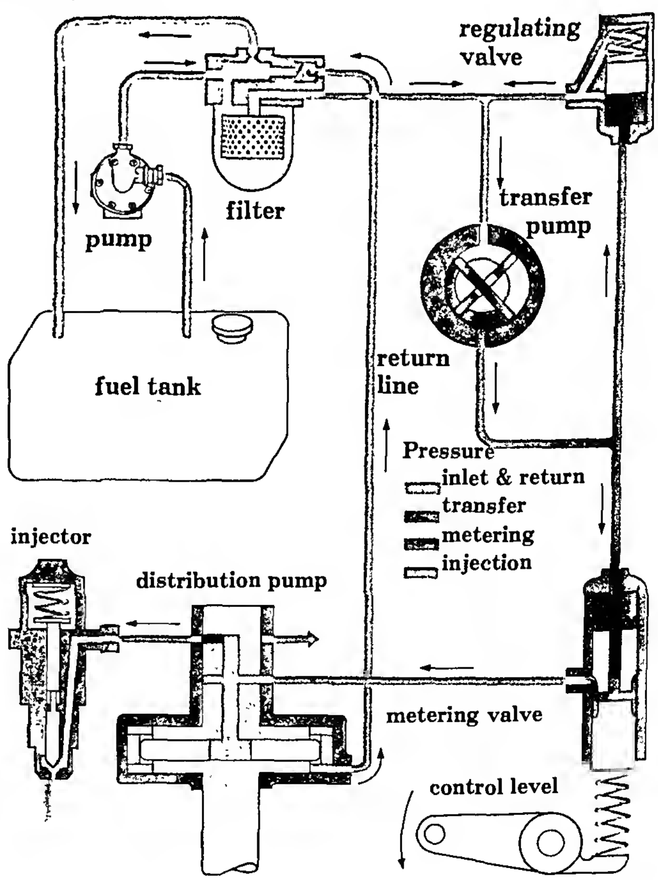
The distributor pump for diesel engines has just one pump element, which sends a charge of fuel to each cylinder in turn. In the center of the pump is a ROTOR. This is driven by the engine, and contains the single pumping element. As the rotor turns, holes in it come into line with a fuel inlet port, one after another. Each time this happens, a jet of fuel enters the rotor. A metering valve controls the exact amount of fuel entering the rotor. The rotor also has a single outlet, or distributor port. This rotor outlet moves past a series of outlets leading to the engine's cylinders, releasing a jet of fuel to each one in turn.

Gasoline fuel injection

In some gasoline engines, the fuel is injected into the intake air in the form of a fine spray. The amount of fuel delivered is regulated by a mechanical metering device or by an electronic control system. Most gasoline engines with fuel-injection systems have one injector for each cylinder of the engine.

See also: CAM, CARBURETOR, DIESEL ENGINE, INTERNAL COMBUSTION ENGINE

Below: A distributor pump injection system for diesel engines. The arrows show the direction in which the fuel flows. The metering valve controls the amount of fuel injected.



Fuses and Circuit Breakers

Electrical equipment can be damaged if too much current flows through it. Fuses and circuit breakers are safety devices that are designed to cut off the current if it becomes too great. Without such devices, equipment could overheat and catch fire.

When an electric current flows through a wire, it generates (gives off) a certain amount of heat. If the current is strong enough, the heat it generates will melt the wire. When the wire has melted, the current can no longer flow. Fuses work on this principle.

Fuses

A fuse is a piece of wire designed to melt when the current passing through it reaches a certain strength. To be effective, a fuse must be the weakest part of the circuit in which it is connected. For example, a cable that would be damaged by a current of 7 AMPERES could be protected by feeding current to it by way of a 5-ampere fuse. Such a fuse would melt if the current rose above 5 amperes. So the cable would never have to carry a current that was too strong for it. If, however, a 10-ampere fuse was used, a current of 9 amperes could pass through it and would melt the cable. For this reason, it is extremely dangerous to use a fuse with a current rating that is too high for the circuit.

Types of fuses

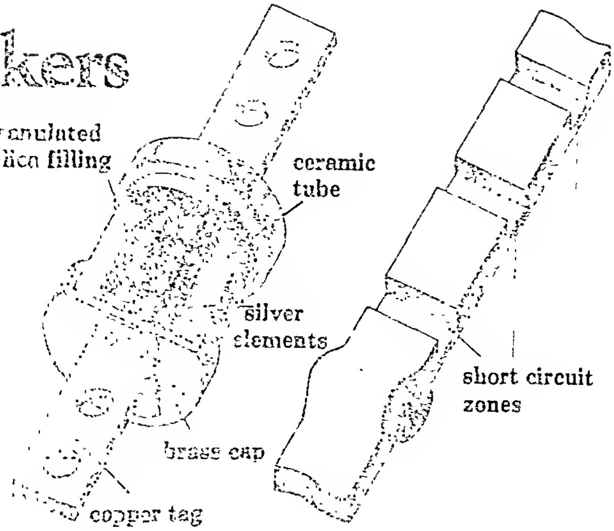
The simplest type of fuse consists of a length of exposed wire connected to two screw TERMINALS. If the wire melts, new wire is connected to the terminals.

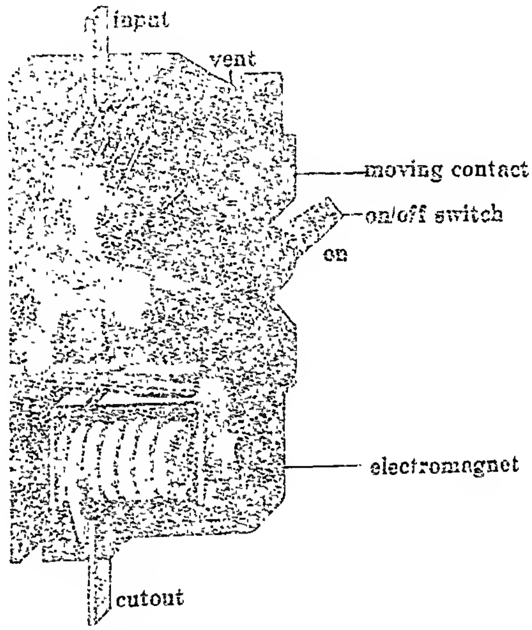
The cartridge fuse is much easier to replace, as it simply clips or screws into its holder. In a cartridge fuse, the wire is contained in a glass or porcelain tube. The ends of the wire are connected to metal caps, one at each end of the tube. Some cartridge fuses are designed to cut excess current very quickly. These fuses have a specially shaped metal element. One or more short, narrow sections in it melt rapidly when the current goes above a certain level.

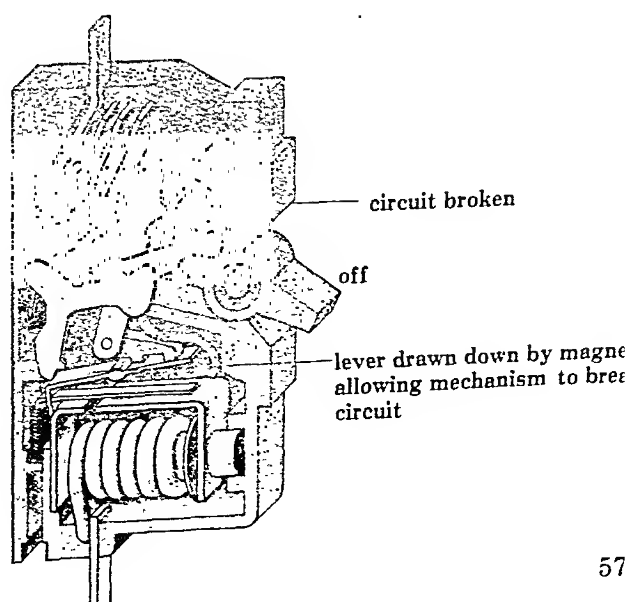
Circuit breakers

Circuit breakers are automatic switches. They cut off electric current when it reaches an unsafe level. In the circuit breaker, the current passes through an electromagnet and through a pair of switch contacts. An excessive current causes the electromagnet to release the switch mechanism. The switch contacts then spring open and cut off the current.

See also: ELECTRICITY, ELECTROMAGNETISM







Right: A cartridge fuse and element (top) and a miniature circuit breaker (center and bottom).

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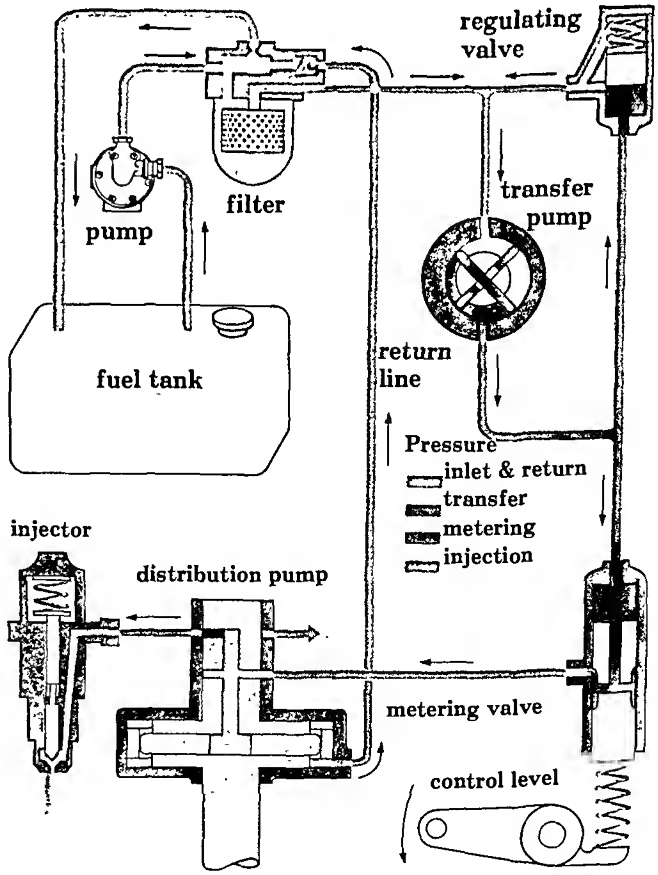

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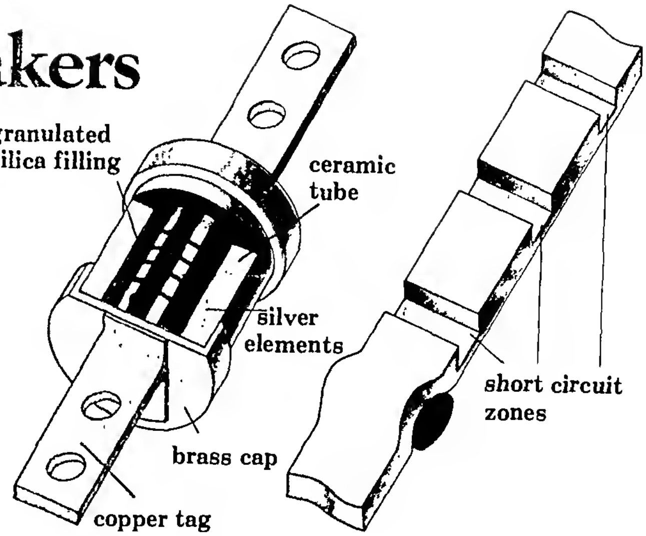
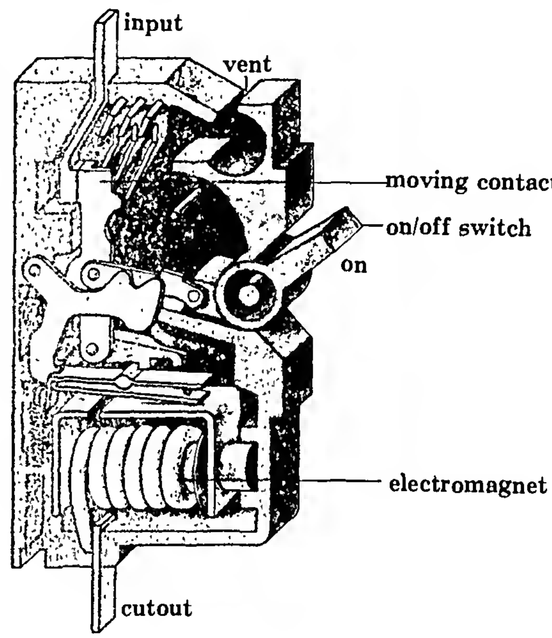
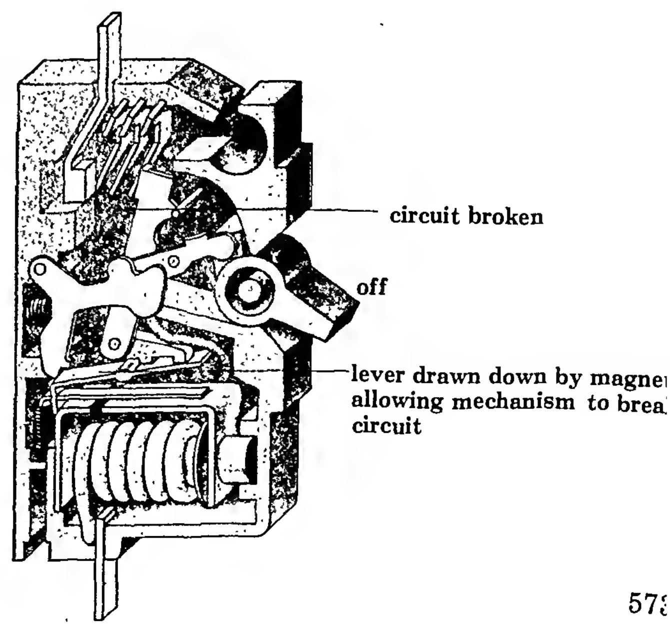






Right: A cartridge fuse and element (top) and a miniature circuit breaker (center and bottom).

Fusion, nuclear

The central part of an atom is called the nucleus. Nuclear fusion is the joining of two light nuclei (plural of nucleus). Together they form the nucleus of a heavier atom. In this process, enormous amounts of energy are released as heat and light. The sun gets its energy in this way.

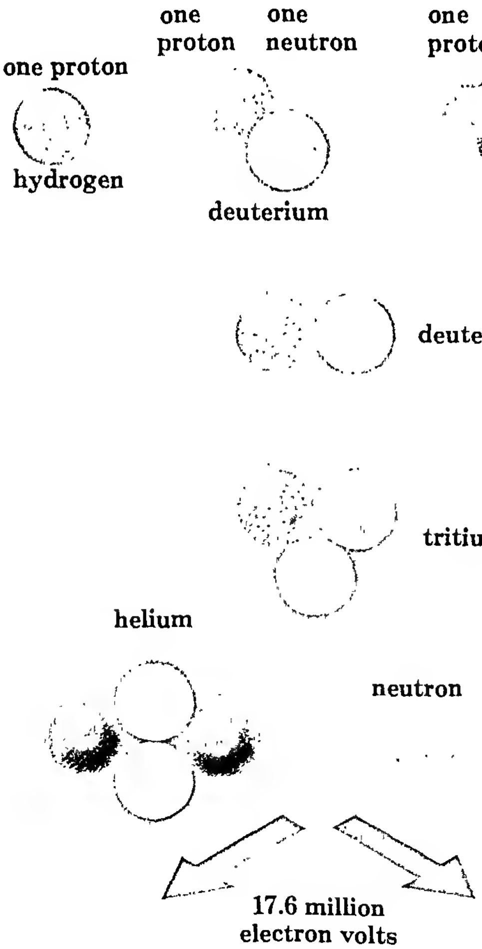
In the most important fusion reactions, the nuclei of hydrogen atoms join together to form a nucleus of helium. Hydrogen has the lightest of all nuclei. Normally, it consists of a simple particle called a PROTON. But, in isotopes of hydrogen, the nucleus also contains one or two NEUTRONS. A hydrogen atom whose nucleus contains one proton and one neutron is called DEUTERIUM. When it contains one proton and two neutrons, the atom is known as TRITIUM. These isotopes of hydrogen are much easier to fuse together than the atoms of normal hydrogen.

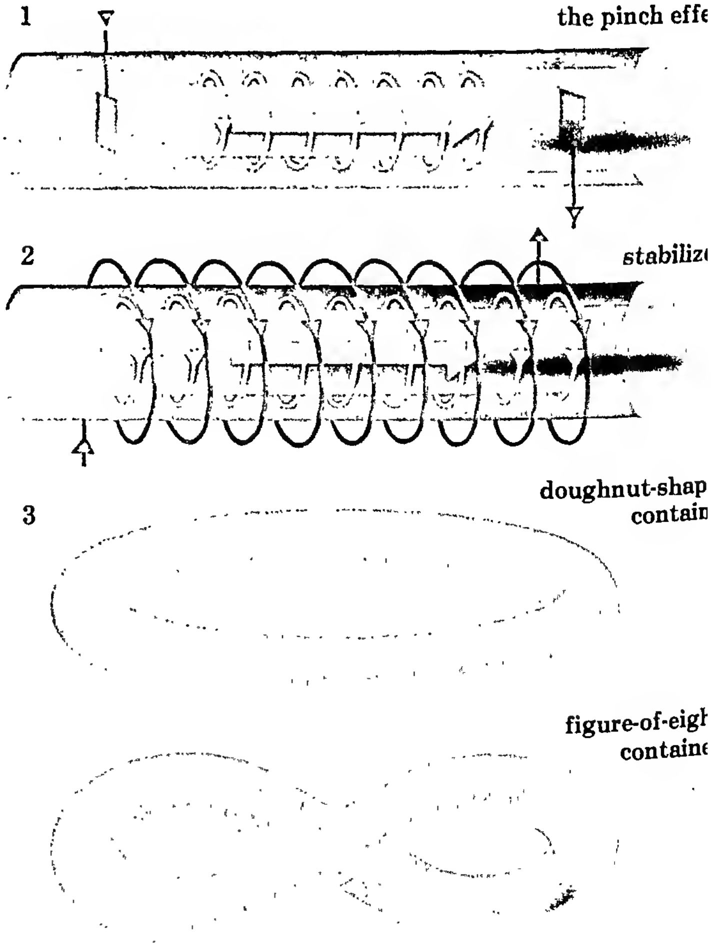
Energy from fusion

The particles in a nucleus are held together by what is called binding energy. When two light nuclei combine to form one heavier nucleus, less binding energy is required. So the difference in binding energy is released when the nuclei combine. This energy is produced by the destruction of matter. Only a small proportion of the original mass of the nuclei is destroyed, but this produces a great amount of energy.

Below left: A nuclear reaction in which deuterium and tritium nuclei fuse together to form a helium nucleus and a free neutron. The energy released by this reaction is shown in units called electron volts.

Below: In fusion reactions, the intensely hot gases would melt the walls of the container. Passing an electric current through the gases will keep them away from the walls (1). The current produces a magnetic field (blue). This "squeezes" the gases, keeping them in the middle. Alternatively, the magnetic field can be formed by passing a current through a coil around the container (2). The container is often in the form of a loop. Two common types are shown in (3).

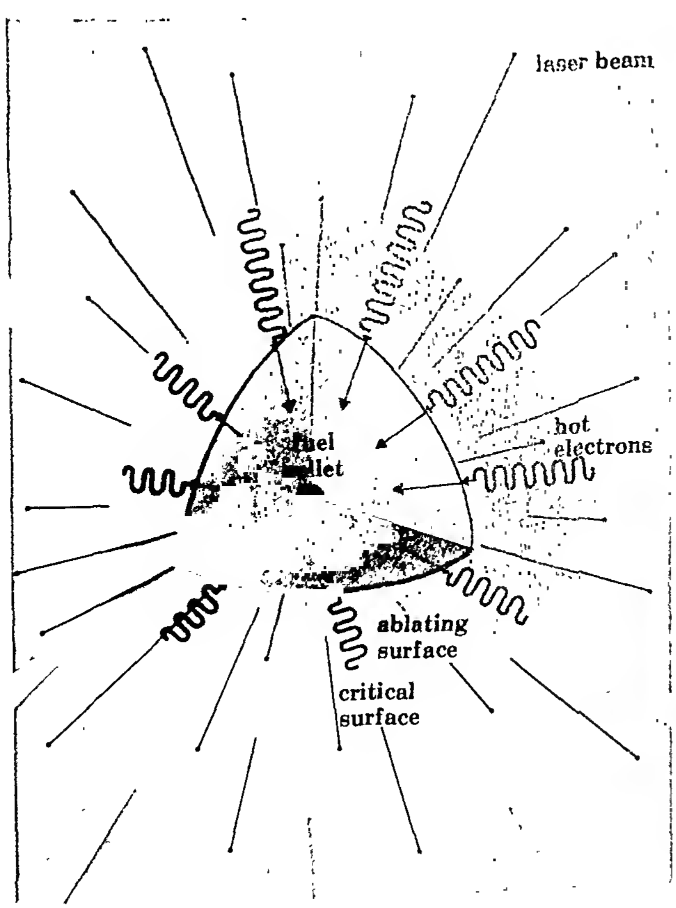




Early in this century, the scientist Albert Einstein stated that mass could be converted into energy. The production of energy in the nuclear fusion process confirms Einstein's theory. He summed up the conversion of mass into energy in one simple equation: $E=mc^2$. This is known as the mass-energy equation. In it, E represents the energy produced when a mass (m) is destroyed. And c represents the speed of light. As c is great (30,000 kilometers per second), c^2 is enormous. So the product of m times c^2 is extremely large, even when m is small. This is why so much energy is produced by the destruction of a very small mass.

If, for example, all the hydrogen nuclei in a barrel of water could be combined in fusion reactions, they would yield more energy than the burning of one million barrels of oil.

Below: Nuclear fusion can be set off by bombarding a solid fuel pellet with laser beams. The high-energy laser light is absorbed at the critical surface. "Hot" electrons shoot inward, heating and ablating (removing) the surface of the pellet. Matter shoots out in a burst of energy. And inward forces blast the remainder of the pellet, causing fusion to occur.



The matter of temperature

For years scientists have worked to control the temperatures of millions of degrees needed for fusion to take place. Then it was found that fusion could be brought about at room temperature by subatomic particles called *muons*. This has led to the possibility of producing nuclear energy through "cold fusion." The announcement in early 1989 by two chemists that they had indeed achieved low-temperature fusion, in a jar of water, proved controversial as scientists around the world tried to duplicate their experiment.

If it were to be possible, a cold-fusion reactor would do away with the heat problem of hot fusion. And fusion as a source of nuclear energy would not result in the radioactive wastes produced by fission, which now powers all nuclear reactors in use.

See also: A-BOMB, ELECTROMAGNETISM, H-BOMB, HYDROGEN, ISOTOPES, NUCLEAR REACTORS

Below: A glowing plasma of neon gas undergoing nuclear fusion.

Gamma Rays

In 1900, a scientist named Paul Villard discovered some strange rays. They could pass through a block of iron one foot (30 centimeters) thick. The rays, called gamma rays, were given off by radioactive atoms.

The nucleus, or center, of an atom contains particles called PROTONS and NEUTRONS. Some elements (simple substances) are RADIOACTIVE. In the nuclei (plural of nucleus) of their atoms, a neutron sometimes decays, or changes, into a proton, an electron and a NEUTRINO. The last two particles escape, and the nucleus is left with a surplus of energy. It emits this energy as a gamma ray PHOTON. These particles make up what we call gamma rays. Unlike the alpha and beta rays also emitted by radioactive substances, gamma rays have no electric charge. Like X-rays, gamma rays contain much energy.

Detection

Gamma rays can be detected by means of a Geiger counter, an instrument containing a tube of argon gas. The energy of the gamma rays rips off electrons from the argon atoms. These electrons release other electrons and, together, they form a pulse of electricity. This is amplified (strengthened) and used to produce a click in a loudspeaker.

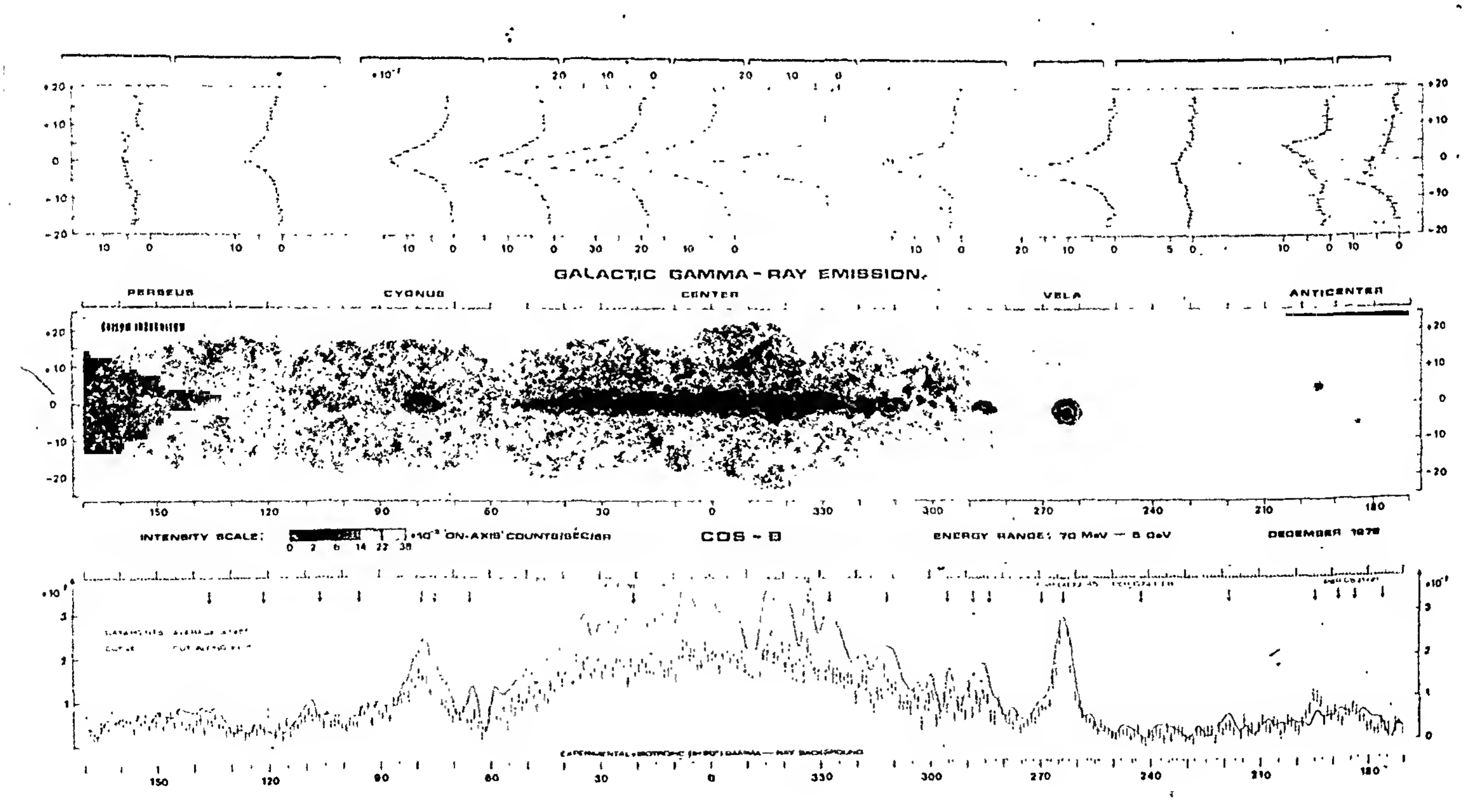
The high energy of gamma rays can harm our bodies. The rays can pass right through and harm vital internal organs. Burns, cancer and even death can result if the body is exposed to too much radiation of this kind. Workers who risk being exposed to gamma rays wear a special badge that contains a piece of photographic film. Gamma rays and light both have the same effect on film: when developed, the film will darken if it has been exposed to either one. Since light cannot penetrate the cover of the badge, whereas gamma rays can, any darkening of the film shows that the wearer has been exposed to gamma rays (or other harmful penetrating rays).

Uses of gamma rays

Although overexposure to gamma rays is harmful, carefully controlled amounts of this radiation are used in medicine. The rays can be used to destroy cancerous body tissues. Small doses can show up internal organs for photography without harming the patient. Gamma rays are also used for sterilizing food and surgical equipment, for strengthening plastics and for finding flaws in metal.

See also: ELECTRONICS IN MEDICINE, X-RAYS

Below: A map of the Milky Way taken at gamma ray wavelength by a satellite called COS-B.

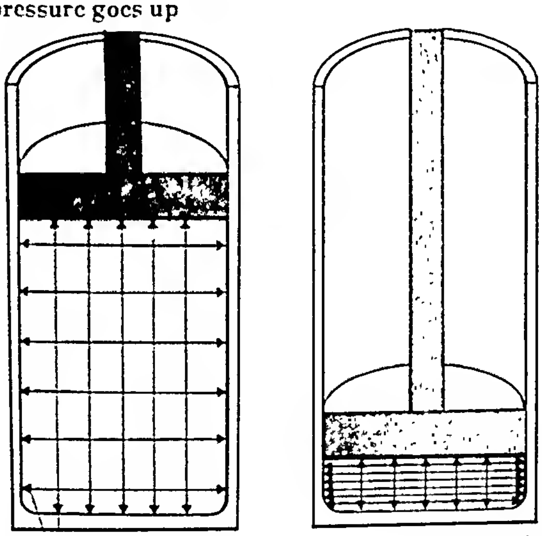


Gas Laws

The gas laws help us understand how gases behave under certain conditions. Boyle's law and Charles' law are about changes in the temperature, pressure and volume of gases. Gay-Lussac's law is about the proportions in which gases are mixed.

Boyle's law and Charles' law are only strictly true for an ideal, or perfect, gas. This means a gas in which the individual molecules take up no space and have no attraction for one another. Of course, no real gas has such properties. But most gases in common use do have extremely small molecules, which are usually far enough apart from them to have little effect on one another. These gases are, therefore, very close to being

Boyle's law
constant temperature:
volume goes down—
pressure goes up

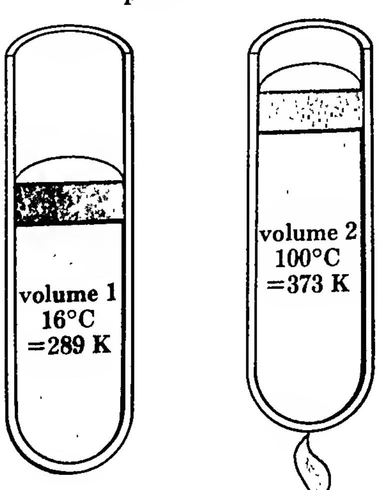


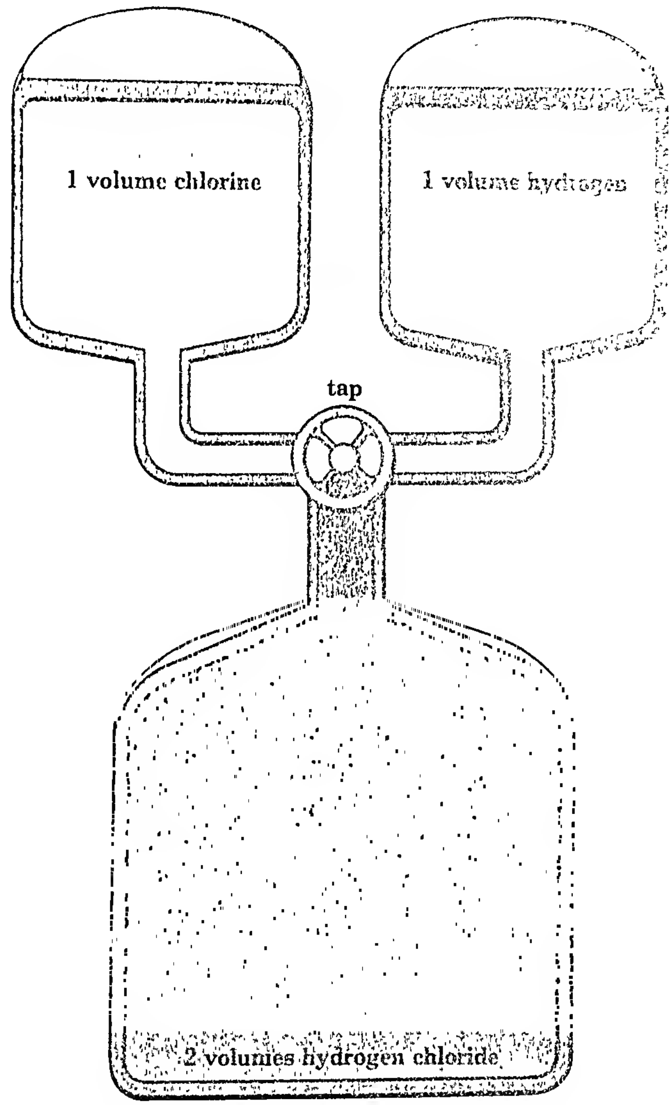
pressure of gas molecules

volume 2
pressure 2

volume 1
pressure 1

Charles' law
constant pressure:
temperature goes up—
volume goes up





Gay-Lussac's law of combining volumes

Above: Gay-Lussac's law states that gases combine in simple proportions. In the example shown, one volume of hydrogen combines with one volume of chlorine.

Left, top: The diagram illustrating Boyle's law shows a gas at constant temperature before and after compression. When the pressure is increased (2), the volume decreases. The product of pressure times volume is constant.

Left, below: Charles' law states that, in a gas at constant pressure, the volume that it occupies is in proportion to its absolute temperature (K).

ideal. So the laws of Boyle and Charles describe their behavior quite well. In general, we can say that these two laws apply to gases at low pressures because then the gas molecules are not pressed together.

Boyle's law

In 1662, the English chemist Robert Boyle announced an important discovery. He had discovered a relationship between the pressure and volume of a gas. Boyle expressed this in the following law: in a given mass of gas, at constant (unchanging) temperature, the volume will vary inversely with pressure. If, for example, a gas is allowed to expand to twice its original volume, then its pressure will drop to half of its original value—provided that the temperature remains the same.

Boyle's law can be explained by considering how the gas molecules behave. The molecules are continually bouncing against the walls of the container. This is how the gas exerts a pressure against the walls. If the volume of the gas is increased, then the molecules will not be so tightly packed together. On average, they will have farther to travel before colliding with a wall of the container. The result of this is that the rate of bombardment on a given area is halved. In other words, the pressure is halved when the volume is doubled.

The law applies only if the temperature stays the same, because any variation in temperature would affect the pressure. If, for example, the temperature increased, the molecules would move faster. This would cause them to exert more pressure on the walls when they bounced against them.

Charles' law

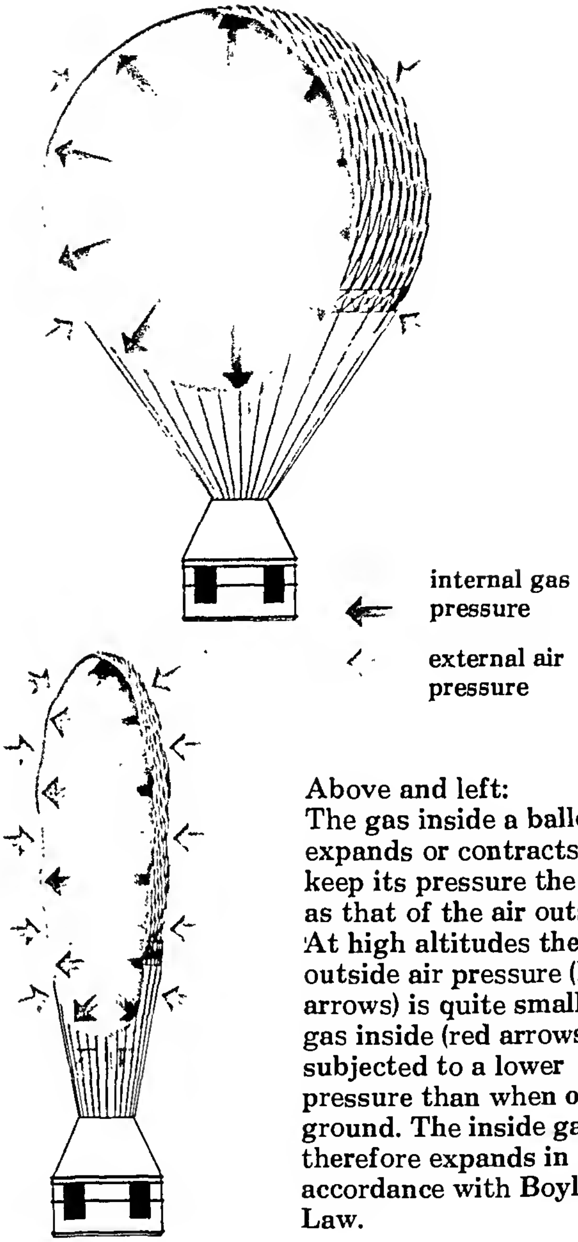
Just over a century after Boyle formulated his law, the French physicist Jacques Charles discovered how the volume of a gas varies with temperature. He found that, if the pressure remains the same, then the volume increases by 1/273 of its volume at 0 degrees C for every degree centigrade rise in temperature. The volume of the gas also decreases by the same amount for every degree that its temperature falls.

This seems to say that the gas would have no volume at all if it was cooled to −273 degrees C. However, all gases become liquids before this temperature is reached, and gas laws do not apply to liquids. In any case, a temperature of −273 degrees C is absolute zero, and can never be reached in practice. It is temperature of an imaginary body containing no heat at all.

Kelvin scale

Absolute zero is the start of the absolute temperature scale, or Kelvin scale. Each degree on this scale is equal to one centigrade degree. So, as zero Kelvin is equal to −273 degrees C, then 273 K is equal to 0 degrees C.

This temperature scale allows us to express Charles' law in a more convenient way. We can say that, at a given pressure, the volume of a gas is in proportion to its absolute temperature.



Above and left:
The gas inside a balloon expands or contracts to keep its pressure the same as that of the air outside. At high altitudes the outside air pressure (blue arrows) is quite small. The gas inside (red arrows) is subjected to a lower pressure than when on the ground. The inside gas therefore expands in accordance with Boyle's Law.

Gay-Lussac's law of combining volumes

In 1808, the French scientist Gay-Lussac studied the volumes of gases in chemical reactions. His results are summed up in his law of combining proportions: when gases react, their volumes and the volumes of any gaseous products are in ratios that can be expressed by small whole numbers. For example, the ratios might be 1:1:2, or 2:1:2.

See also: BALLOONS

Gas Production

The modern gas industry began in the late 1700s, when it was used for lighting. The use of gas for heating and cooking did not become widespread until after 1850. Today, the types of gas most used are coal gas, oil gas and natural gas. In addition, liquid butane and propane are used in some areas.

The first company to manufacture and supply coal gas on a commercial basis was founded in England by Matthew Boulton and James Watt. They hired a man called William Murdock to build steam engines, and it was his experimental work with gas that led to the company's involvement with the gas industry.

In 1814, Boulton and Watt handed over the development of the industry to the Gas Light and Coke Company in London. They developed a system for distributing gas by pipeline from a central gas works to the customer. The chief engineer on the project was Samuel Clegg, who had worked with Boulton and Watt.

In the United States, the gas industry began in Baltimore, Maryland. In 1816, the city council gave Rembrandt Peale permission to manufacture gas and distribute it to the town through pipes laid under the streets. The use of natural gas, rather than manufactured gas, began in the mid-1800s. The first firm to become involved in this field was the Fredonia Gas Light and Water Works Company, which was formed in 1858. Today, there are more than 100,000 natural gas wells in the United States. Natural gas deposits have also been found in North Africa, Russia, Australia and off the northern European coast.

Coal gas

Coal gas is made by the CARBONIZATION of coal. This means that coal has to be heated in the absence of air. The heat drives off the gas and, at the same time, gives off several useful byproducts. The most important elements (simple substances) found in coal are carbon, hydrogen, oxygen, nitrogen and sulfur. The hydrogen and carbon form the basis of coal gas.

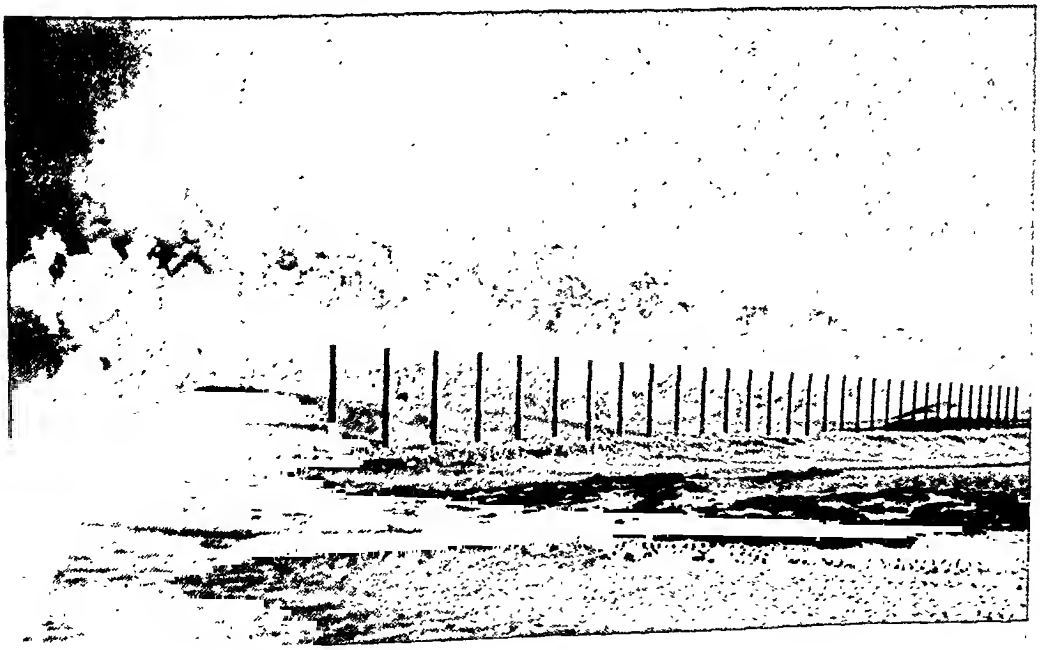
Many factors affect the exact composition of coal gas. These include the type of coal used, the temperature at which the gas is made, and the type of container in which the coal is carbonized.

The crude gas obtained from the coal has to go through several stages (purification) to remove unwanted parts, such as ammonia, hydrogen sulfide, hydrogen cyanide, tars and various hydrocarbons.

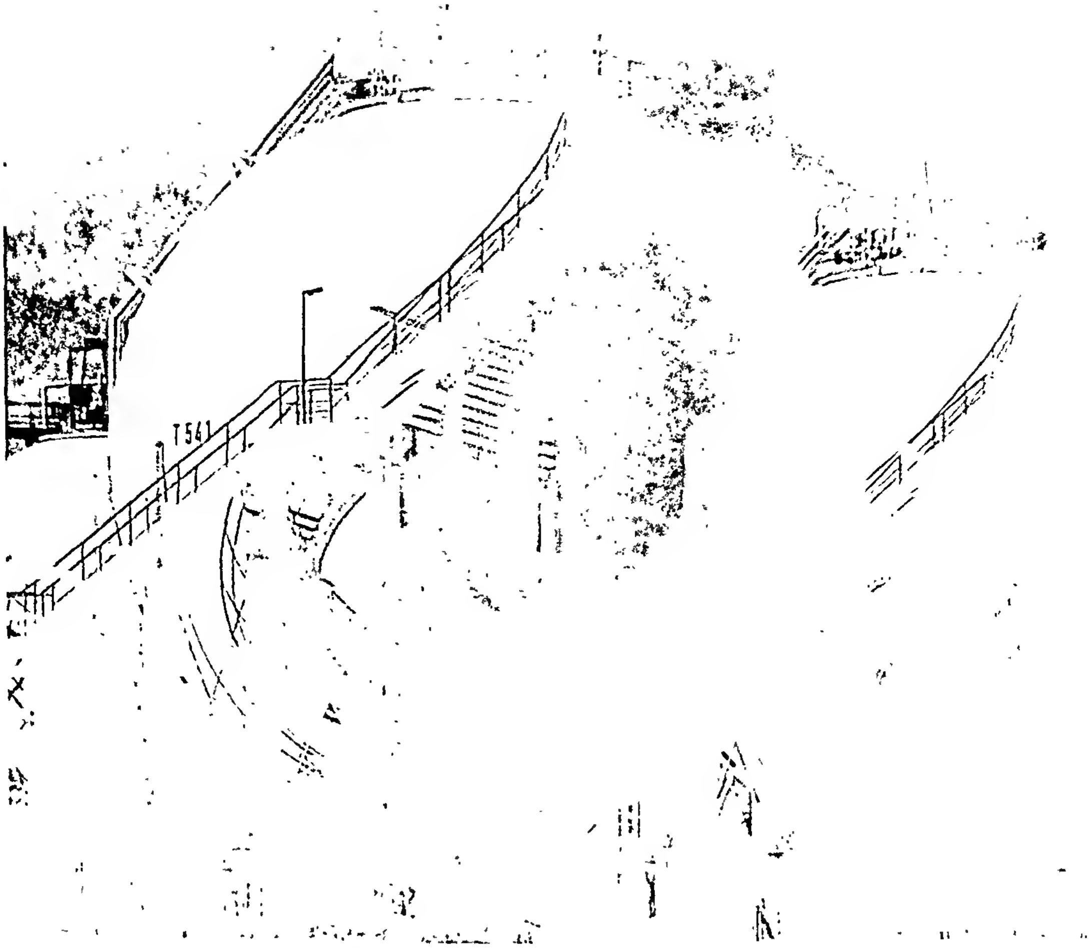
A typical purified coal gas might contain about 50 percent hydrogen, 25 percent methane, 10 percent nitrogen, and small amounts of carbon monoxide, carbon dioxide, ethylene, benzene and oxygen.

The coal is heated in containers called retorts. The earliest retorts were cast-iron pots that were heated by burning coal underneath them. Although the retorts did not have to stand up to very high temperatures, they lasted only a short time. Also the low temperature did not drive off all the gas from the coal. However, retorts made from heat-resistant firebricks were soon developed. These allowed the carbonization temperature to be raised to around 1742 degrees F (950 degrees C).

As natural gas became more widely used in the 1930s, so coal gas became less important in the United States. However, the thought that natural gas supplies



Left: Natural gas being burned off at an oil field in Abu Dhabi, near the Persian Gulf. The oil is pumped out after the gas has been removed. Burning gas like this is wasteful. But it would cost too much to transport the gas to markets, as these are a long distance away.



Right: Storage tanks for liquefied natural gas. In liquid form, the gas is greatly reduced in volume. This makes it much easier to store and transport in large quantities. Specially built tankers with pressurized holds can be used to ship the gas to other countries.

might run out has recently led to renewed interest in coal gas production.

Carbonization

When coal arrives at a gasworks, it is first broken down into small pieces. The coal is then taken from the breaker to overhead storage hoppers in the retort house. From here, the coal is fed into the retorts, as required.

The retorts are surrounded by a heating chamber, which is supplied with producer gas. This is a cheap, low-grade gas used in many industries. Also called Siemen's gas, it is made by blowing air, or air and steam, through a bed of heated fuel, such as coal, coke or lignite (a brown coal with traces of a woody structure).

The burning producer gas heats the coal to a temperature of about 2462 degrees F (1350 degrees C). This causes the coal to give off gases, steam and tarry VAPORS. The residue of the coal becomes plastic, and the gas passing through it gives the POROUS structure of the solid residue, coke.

The gas, steam and vapors pass from the retorts into a section called the collecting main. Here, most of the tarry vapors are removed. The gas and impurities then pass into a condenser, where they are cooled. The drop in temperature causes many of the impurities t separate. These appear as tar and ammoniacal liquo which are run off into a well. The tar contains pitcl creosote, carbolic and other oils, naphtha and a sma amount of water. The ammoniacal liquor is formed b steam condensing and dissolving most of the ammoni and other impurities in the gas. These other impuritie include phenols and various sulfur and hydroge compounds.

A device called an exhauster then forces the ga through a series of washing and purifying stages. Thes remove the last traces of tar, ammonia, hydroge sulfide, naphthalene and benzole. A drying plan removes any remaining moisture, as this would rus any iron pipes in the system.

After leaving the drying plant, the coal gas passes t a gasholder, where it is stored until it has to be piped t the consumers.

Oil gas

Gas was first made from crude oil by using heat t "crack" it. Cracking means splitting the large molecules of substances, such as oil, into smaller ones. The heat was produced by means of steam at a temperature of more than 1832 degrees F (1000 degrees C). An improved cracking process called catalytic

Gears

Gears are toothed wheels used in machines and engines. Automobiles, bicycles, clocks, drills and many other devices have gears. They are sometimes called cog wheels. Gears are used to transmit motion from one moving part of the machine to another. The teeth of one gear fit in between the teeth of the other.

Besides simply transmitting motion, gears also affect the speed at which machines run. Suppose that two shafts are fitted with simple, flat gears that mesh with each other. If the two gears are of the same size, then, when one shaft is turned, it will make the other one turn at the same speed.

Now suppose that the shaft doing the driving is fitted with a larger gear. It may, for example, have 60 teeth around its edge, compared with 20 teeth on the other gear. In this case, one turn of the large gear will make the small one turn three times. So the speed of the driven shaft will be three times the speed of the driving shaft. An arrangement like this is called a speed increaser. If, on the other hand, the small gear is used to drive the large one, then the arrangement is called a speed reducer. The small gear would have to turn three times to make the large one turn just once.

Gear ratios

The larger of a pair of gears is called the gear, and the smaller one is called the pinion. If, for example, the gear has three times as many teeth as the pinion and the gear is driving the pinion, then the combination of the two is said to have a gear ratio of 3:1 (three to one). If the pinion is driving the gear, then the ratio is 1:3. In either case, each tooth on the pinion comes into contact with the gear three times for each revolution of the gear. So the teeth on the pinion do three times as much work as the teeth on the gear. Because of this, the pinion is sometimes made of harder material in order to extend the working life of the machinery.

The gear ratio is chosen so that the power of the machine is transmitted at a usable speed. More often than not, this means that a reduction in speed is necessary because most engines and motors have a

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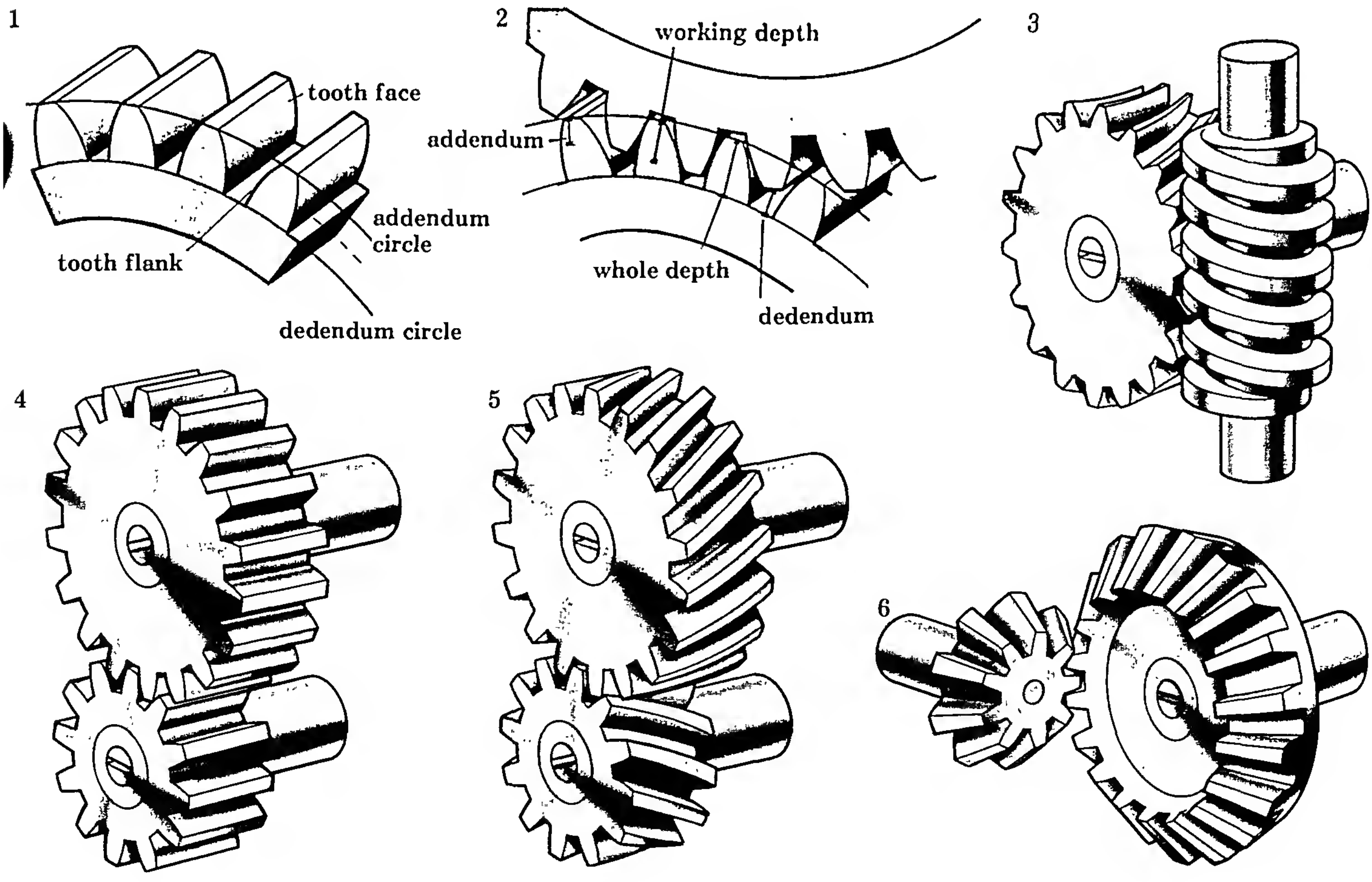

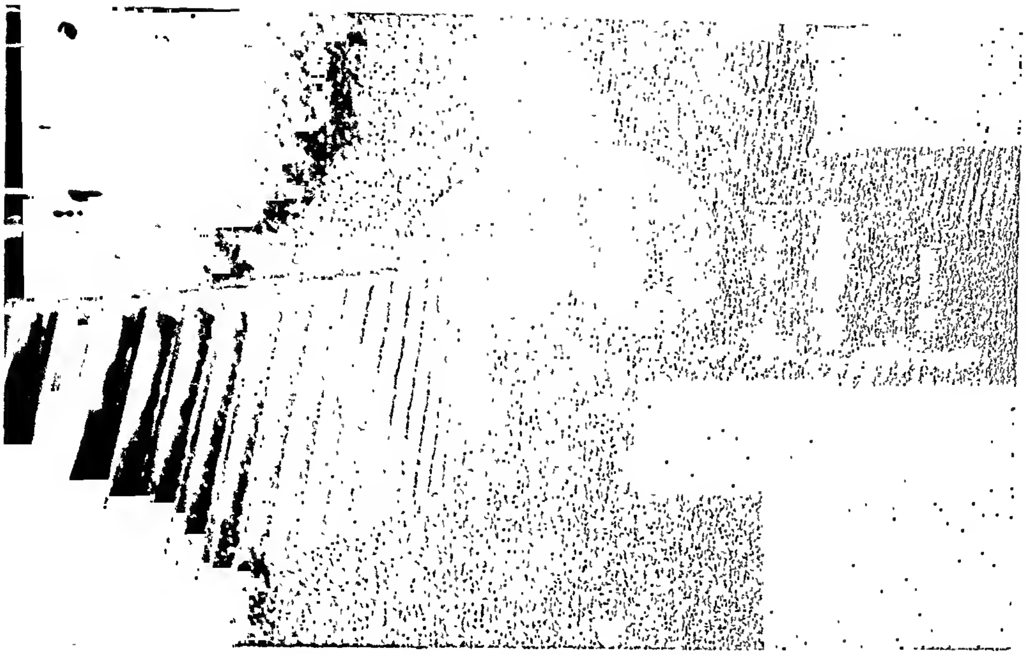

Left: An engineer checks the teeth on the gears of a ship's diesel engine. The gear he is checking is the pinion. It has two sets of helical teeth.

running speed that is too high for the work that they have to do. So a low gear ratio is used to obtain a more suitable speed. Many electric drills contain gears because if a drill runs too fast, then the cutting bit will tend to overheat and wear out quickly.

In some machines, gears can be changed for different speeds. In an automobile, for example, the driver can usually choose from a range of three to five gear ratios for forward movement, plus a reverse gear to make the vehicle move backward.

Idlers

When one simple gear drives another, they turn in opposite directions. If it is required that they turn in the same direction, a third gear called an idler can be used between them. The direction of rotation is reversed twice, therefore the final gear turns in the same direction as the first one.

The size of the idler has no effect on the final speed. When the driving gear moves it around by a certain number of teeth, then the idler will move the final gear around by the same amount. So, as far as speed is concerned, the situation is the same as if the driving gear was turning the final one directly.

Types of gears

The simplest, and most common, type of gear is called the spur gear. Other types are called bevel gears, helical gears and worm gears.

Spur gears

Spur gears have straight teeth and are used to transmit power between parallel shafts. From the side, the teeth can be seen to have a curved shape. The sides of the teeth must be curved so they will not make a lot of noise and cause too much vibration, especially when running at high speed. This noise and vibration uses up energy, so, without curved sides, the straight teeth would also be inefficient and tend to wear out quickly. Curved sides, on the other hand, intermesh smoothly and quietly.

The curved shape of the teeth is called INVOLUTE. This shape has been found to be best for maximum efficiency. Even if the distance between the shafts is not quite correct, the curved surface still transfers most of the energy from one tooth to the other.

Bevel gears

Bevel gears are shaped like parts of cones. They are used to transmit power between shafts whose axes (plural of axis) cross (figure 6 opposite).

Helical gears

Spur gears and bevel gears sometimes have spiral teeth. They are then called helical gears. With suitable design of the spiral, shafts at any angle to each other can be linked using helical gears.

Worm gears

A pinion with a thread around it, like that on a screw, is called a worm. The worm meshes with an ordinary helical gear, and usually drives the gear to give a great reduction in speed. The gear cannot usually drive the worm gear.

See also: BICYCLE, CHAIN DRIVE, FREEWHEEL

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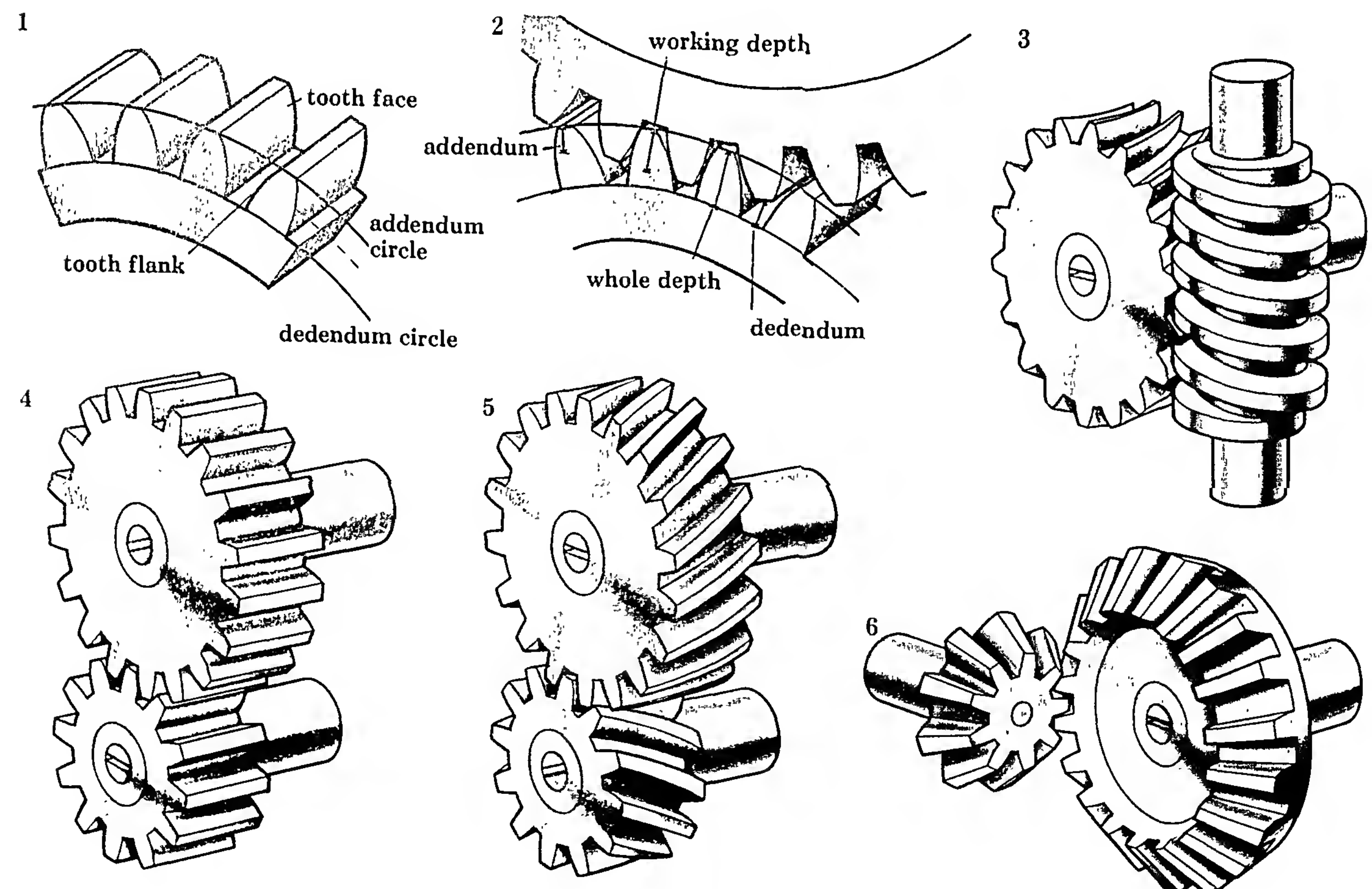

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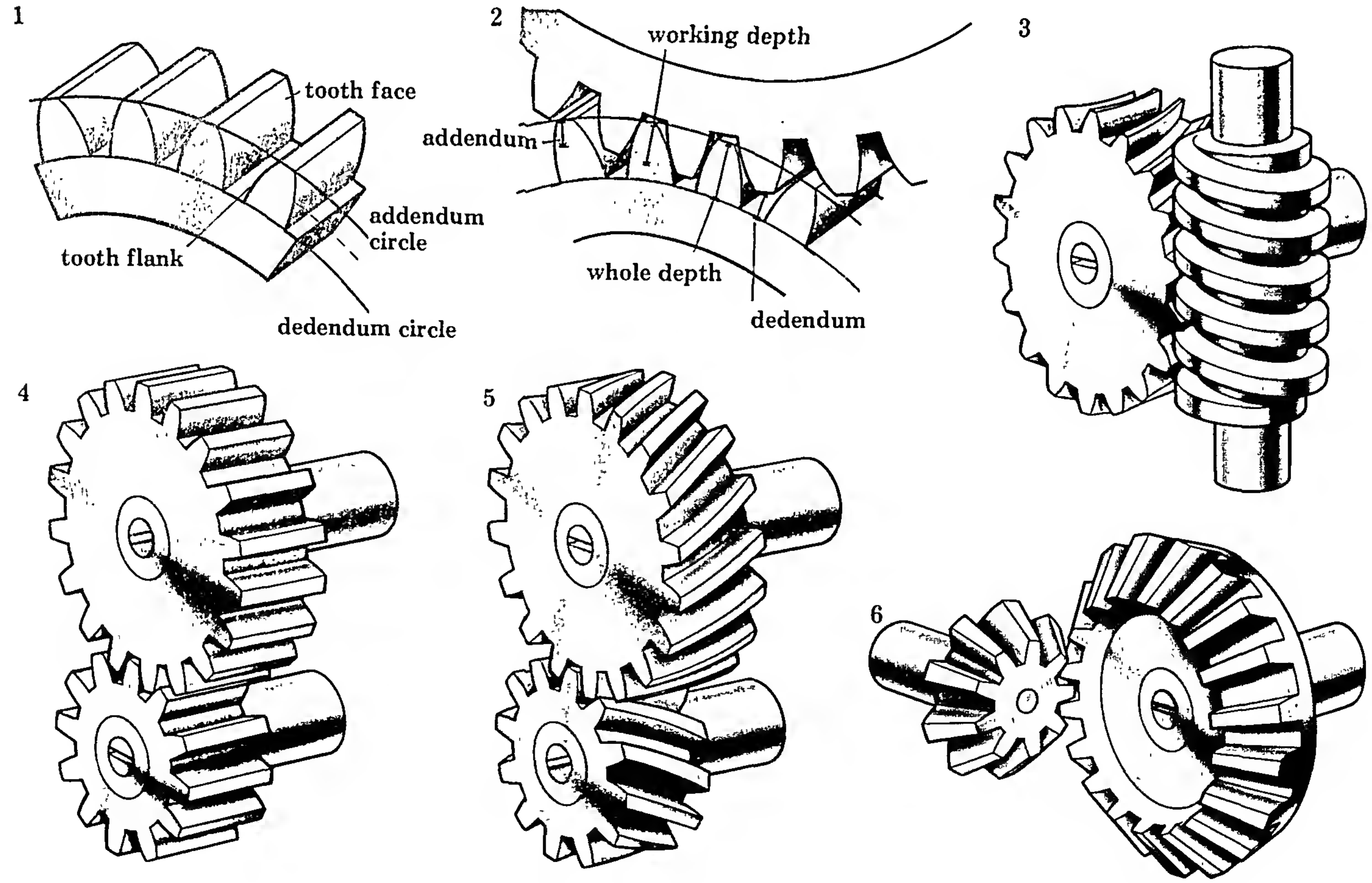

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See also: BICYCLE, CHAIN DRIVE, FREEWHEEL

Geiger Counter

The Geiger counter is a device for finding charged particles. It was invented by Hans Geiger and E. W. Muller in 1928. The Geiger counter was once an important instrument in the studies of charged particles in atoms. It was also widely used to find radioactive substances. More accurate detectors are now available.

Construction

The most popular type of Geiger counter has a discharge tube connected to a high-voltage supply and an amplifer and loudspeaker. The tube, which is made of glass, has a copper cylinder with a wire running through it. A low-pressure atmosphere of argon gas is sealed inside the tube. The cylinder and wire are connected through one end wall of the tube to the high-voltage supply. The cylinder, which is connected to the negative line of the supply, is called the negative electrode, or cathode. The wire is connected to the positive line of the supply and is called the positive electrode, or anode.

Operating principles

A high-energy charged particle is able to pass right through the glass tube. Inside the tube, the particle knocks ELECTRONS out of the gas atoms. Electrons are negatively charged. As opposite charges attract, the released electrons move toward the positively charged wire anode. The damaged atoms, having lost electrons, now have an overall positive charge. In this state, they are called argon ions. These ions are attracted toward the negatively charged cathode.

Electron avalanche

The high positive voltage on the wire makes electrons rush toward it at such speed that they kn further electrons out of the argon gas. These electro too, rush toward the wire, knocking even m electrons from the gas atoms. This effect is known electron avalanche.

When the positive ions reach the cylinder, they str it with such force that still more electrons are releas These join the other electrons rushing toward the an wire. As a result, so many electrons strike the wire tl they form a distinct pulse of electric current. This pu is amplified (strengthened) and fed to a loudspeak where it makes a click. Any clicking in the loudspeal therefore indicates that there are charged particles n the tube. Simple Geiger counters like this became w known as standard equipment for uranium pr pectors. Because it is radioactive, uranium throws charged particles and thus activates the Geig counter.

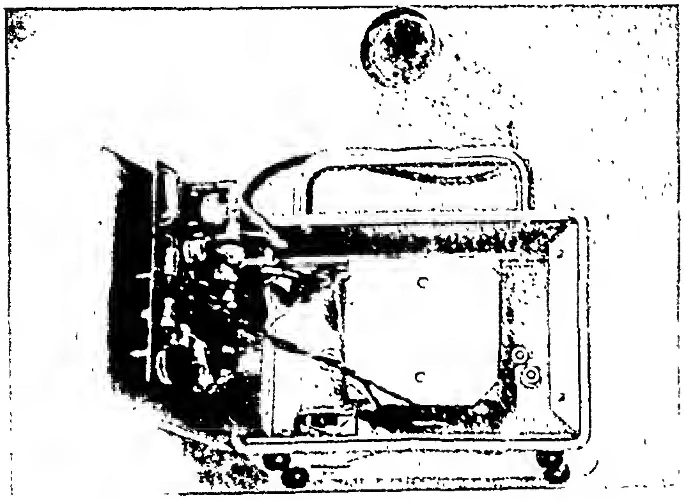
Below left: Using a Geiger counter to prospect for radioactive materials, such as uranium. The sensiti tube of the instrument protrudes from the front.

Below: Testing a damaged eye. The amount of radioactive phosphorus reaching it from an injectio into the blood is measured with a small Geiger counter.

Background radiation

When a Geiger counter is switched on, irregular clicks will always be heard. These are caused by cosmic rays, or by natural radioactivity. Cosmic rays are very high energy particles that shower onto the earth from outer space. Natural radioactivity is the release of particles from chemical substances in the surroundings. The strength of this radiation can be judged from the rate of the clicking.

Below: A portable Geiger counter of the sort mainly used in laboratories and factories. This machine gives a clicking noise, as well as a visual display, of the radiation count.



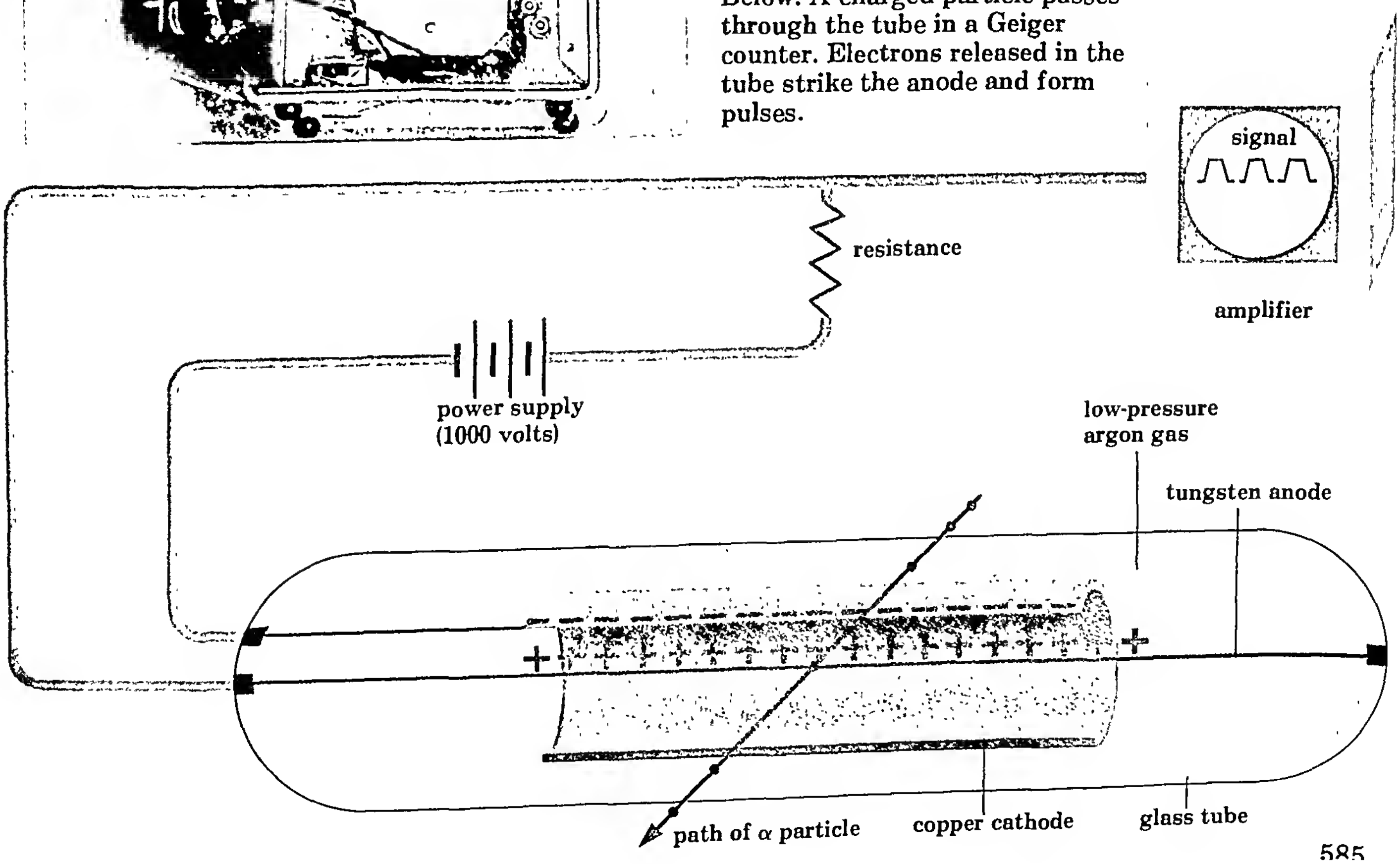
Limitations

A Geiger counter can detect charged particles, but cannot tell their exact positions. A click in the loudspeaker simply indicates that a particle has passed through some part of the tube. In many experiments, scientists need to know the exact positions of particles, so the Geiger counter is of little use in this work. Another problem is that the times of arrival of particles often need to be measured. The first click can be measured to about one-millionth of a second. In most cases, this is accurate enough. But no further particles can be detected for about one ten-thousandth of a second. This is because the surge of electrons to the anode in the tube cancels its positive charge for a moment. So the tube stops working until the anode is charged.

Another limitation of the Geiger counter is that it cannot tell the difference between various charged particles. However, the instrument can be set to give a reading in proportion to the number of electrons let out by the particle in the tube. The type of particle can usually be known from this reading. A Geiger counter operated in this way is known as a proportional counter.

See also: GAMMA RAYS, URANIUM

Below: A charged particle passes through the tube in a Geiger counter. Electrons released in the tube strike the anode and form pulses.



Generator

Electricity is a form of energy. A generator changes movement, another form of energy, into electrical energy. Generators can be small enough to hold in one hand or as large as a house. There are huge generators that can make enough electricity for cities of millions of people.

There are two main types of generator: alternating current (AC) generators and direct current (DC) generators. Most big generators are of the AC type. Direct current generators produce electric current that flows in the same direction all the time. Alternating current generators produce electricity that changes (alternates) direction 50 or 60 times every second—it has a frequency of 50 or 60 Hertz. Both types of generators work in much the same way.

How generators work

The space around a magnet is occupied by a magnetic field. This field can be "mapped" by finding the direction of the magnetic force at different points around the magnet. If you move a conductor such as a coil of wire through a magnetic field, an electric current flows in the conductor.

A simple generator is like a simple electric motor. A coil of wire, wound on an iron core, is made to rotate between the poles of a permanent magnet. (A permanent magnet is made from an alloy that, unlike soft iron, does not lose its magnetism when the magnetizing force is taken away.) When the coil rotates, it passes through the field of the magnet, so a voltage is set up in the coil. As the coil goes around, the angle at which it cuts through the magnetic field changes all the time. This causes corresponding changes in the strength of the VOLTAGE in the coil.

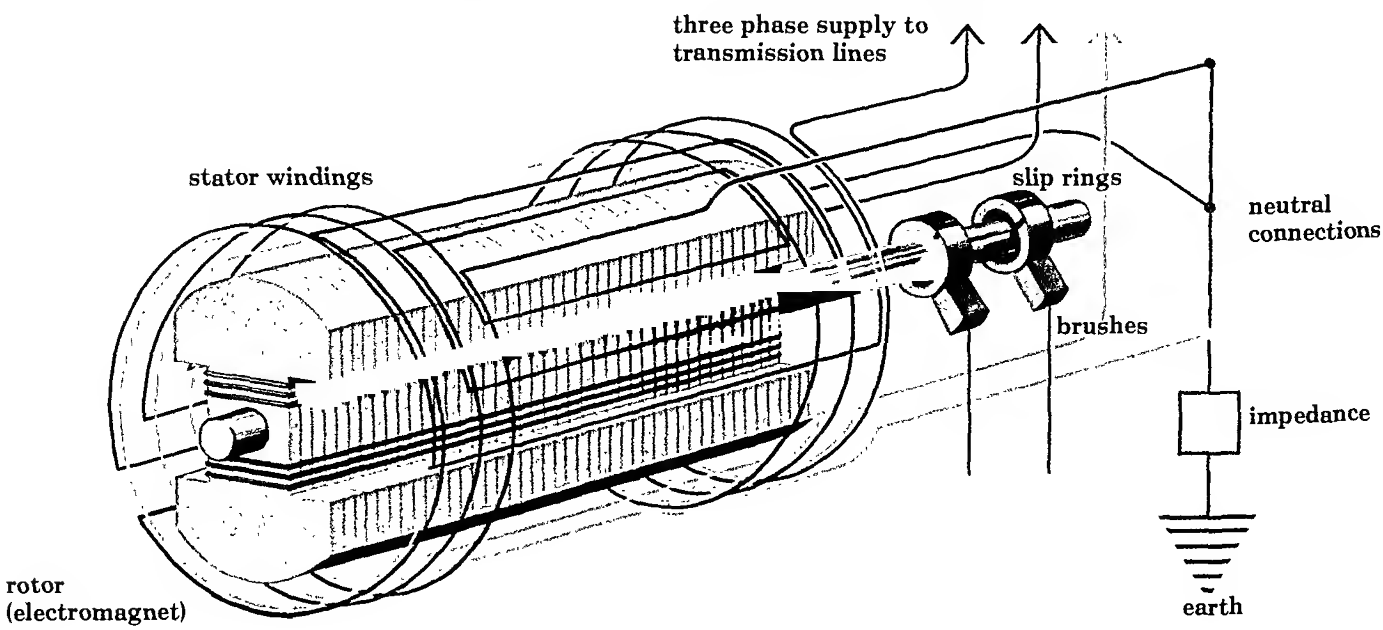
The rotation of the coil also causes the voltage to change direction. This is because the wire in the coil keeps changing the direction in which it cuts through the magnetic field. The result is a voltage and therefore a current that grows from zero to maximum, decreases to zero, grows to maximum in the opposite direction, and then decreases to zero again. This is an alternating current (AC) and the type of generator that produces it is called an AC generator or an alternator.

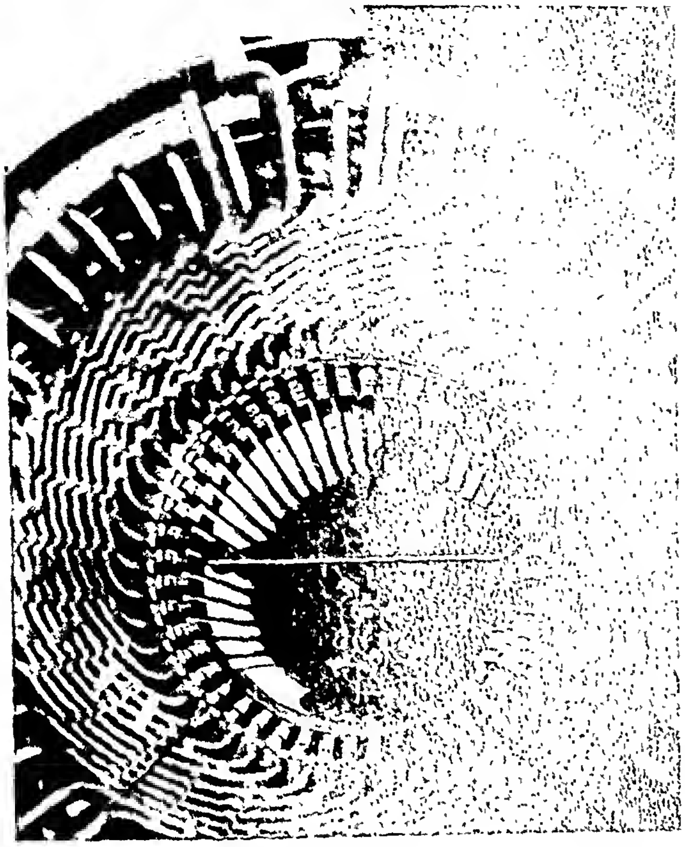
The current generated in the coil must be conducted away. Wires cannot be connected to the turning coil, so a generator has two flat metal rings called slip rings attached to the coil. The ends of the coil are attached to these rings. A pair of fixed carbon brushes makes contact with the rings as the coil turns. The voltage generated in the coil appears across the brushes, giving an alternating current. (Brushes are merely solid pieces of carbon that are soft enough to make good contact with the slip rings.)

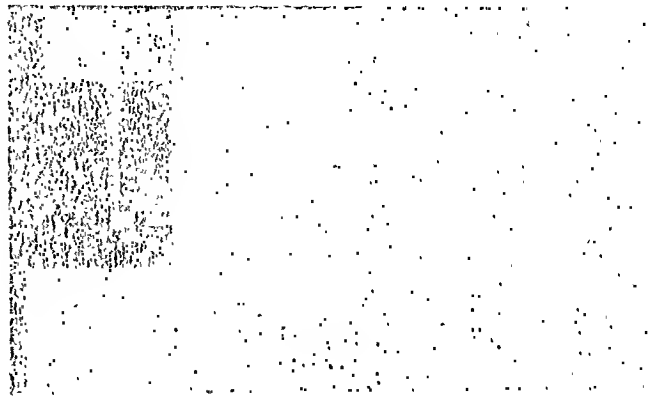
The DC generator

For many purposes, such as charging automobile batteries, driving electric locomotives and plating

Below: How the windings are arranged in a typical generator. The central rotor is an electromagnet (green winding). It is powered through slip rings which collect current from brushes, also shown in green. The electromagnet rotates inside the stationary red, blue and yellow windings, each of which goes two thirds of the way around the rotor. This produces one cycle of three-phase electricity for each turn of the rotor.







Above: A cutaway view of an automobile alternator. The output is converted to DC current.

Left: Inside a big generator. The windings on the outside are the ones that produce the current.

metals, we need current that flows in one direction only. To get direct current from a generator, a device called a COMMUTATOR (reversing switch) is used instead of slip rings. The current flowing through the coil still alternates, but the commutator reverses the connections to the carbon brushes every half-turn. This means the current always leaves the coil through one particular brush and returns through the other one.

Larger generators

The type of generators described so far have been small machines. Today, only the smallest generators have permanent magnets. In most cases, electromagnets are used because they give a much stronger magnetic field. In most large AC generators these field coils are ENERGIZED by a separate DC generator.

In the generators discussed so far, the coils in which the current is INDUCED have always been the moving part—the rotor of the machine. But slip rings and brushes are troublesome if they have to carry large currents. In large generators this is avoided by making the field coils rotate inside the coils that generate the electricity. The wire that cuts through the magnetic field to make the electricity is called the armature. The armature in large machines is made up of many coils of wire arranged in a ring. This is the stationary part of the machine, and in a big machine there may be 30 miles (50 kilometers) of copper wire in the armature coils.

In large generators, the slip rings are used to carry the direct current to the rotating electromagnets. Wires connected to the stationary armature coils take the alternating current direct to where it is needed in the factory or power grid. It is easier to send the weak current for the electromagnets through slip rings instead of the very large generated current.

The uses of AC generators

Power station generators are nearly all of the AC type. The main reason for this is that it is easy to transform (change) the voltage from the generator to any required amount before sending the electricity over long distances. Transformers can increase or decrease alternating current but not direct current. The voltage produced by many large generators can be about 20,000 volts. By means of a transformer, this can be increased to 300,000 volts before the electricity is sent along power wires over many miles.

Sending electric current along power lines at high voltages cuts down the power loss in the wires. Other transformers reduce the voltage of the electricity so that it can be used in homes and factories.

The output of modern generators is always in the form of three-phase AC. The coil windings are split around the machine (see diagram) so that there are really three different outputs. Each output is displaced from the next by a third of a revolution. Power in this form is cheaper to transmit than single-phase power.

See also: AUTOMOBILE, ELECTRICITY, ELECTRIC MOTOR, ELECTROMAGNETISM, MAGNETISM

Genetics

When someone says, "She has curly hair just like her father's," or "You certainly look like your mother," they are making remarks that have to do with heredity. Genetics is the scientific study of how and why we inherit certain physical and mental characteristics from our parents and ancestors—and pass them on to our children and descendants.

All people have the same general appearance and basic features—eyes and mouth, arms and legs, hands and feet, skin and hair. But no two people of the more than 3000 million on earth are exactly alike. Some are tall, some are short. Some are intelligent, some are dull. Some are healthy and whole, some are ill and deformed.

Both the sameness (all the things that make us alike) and the variety (all the things that make us different) come from the genes in our body. In fact, the NUCLEUS (central core) of each cell of the body contains a kind of blueprint, or plan, of ourselves. We have received this blueprint from our parents, they from their parents and so on back in our ancestry. We will pass the plan on to our children, they to their children, and so on into future generations.

Heredity is the process of receiving and passing on shared characteristics, that is, our ancestors giving to us (or "sharing" with us) certain features. These features can be the shape of the nose, the color of hair, good or bad vision, quickness of mind, and so on. Genetics is the study of the way heredity works.

Above: Gregor Johann Mendel, the Austrian monk who was also a scientist. He published his great work on heredity in 1866.

The pioneering of Mendel

Gregor Johann Mendel (1822–84) laid the foundation for modern genetics. Mendel was an Austrian monk who taught at a secondary school in Brno, Czechoslovakia. While teaching, he also carried out a long series of experiments on garden peas and other plants to find out how to grow better varieties. These experiments lasted for 25 years from 1843 until 1868, when he became head of the school and had no more time for scientific study. His work was published in 1866, but no one paid any attention to it during his lifetime.

Mendel's theory states that the shared characteristics we inherit come about by the combination of two units carrying hereditary information, and that we get one unit from each parent's reproductive cells. He also explained that some of these units are dominant (able to control) and others are recessive (held back, but ready to come forward when the time is right).

In the early 1900s, Mendel's work was rediscovered by three scientists working alone in three different places. These were Hugo de Vries, K. E. Correns, and Erich Tschermak. The beginning of genetics really dates from the continuation and development of Mendel's fundamental ideas by these three.

They discovered that chromosomes and genes are the means of transmitting the special features we inherit. The chromosomes carry the genes, and the genes from each parent go into the fertilized (able to reproduce) egg from which a baby starts to grow.

Chromosomes

The nucleus of every cell in our body carries exactly 46 chromosomes, which are thread-like structures arranged in pairs of 23. The paired chromosomes are shaped something like a thin, uneven X, and are so tiny that they can be seen only with a powerful microscope. Twenty-three of the chromosomes in each cell come from the mother, and 23 from the father.

The sex cells are different, however. They have only 23 chromosomes in them, and they only reach the necessary 46 when they come together in a fertilized egg. There is another big difference in sex cells. The sex chromosome in males is not the same shape as other paired chromosomes. One of the pair is small and hook-shaped. This is known as the Y chromosome, so the male chromosome is shown as XY. Female sex cells are shown as XX.

When an egg cell (female) or sperm cell (male) is being roduced, the cells divide in a special way called neiosis. Then half (23) of the chromosomes go to each gg and half to each sperm. One of these is always a sex hromosome. The 23 chromosomes from the egg join he 23 from the sperm in what is called homologous similar in structure and duties) pairs, and they make ıp the 46 chromosomes that every cell has. The 46 hromosomes carry about 100,000 genes, which are ound in a row all along the length of the chromosomes.

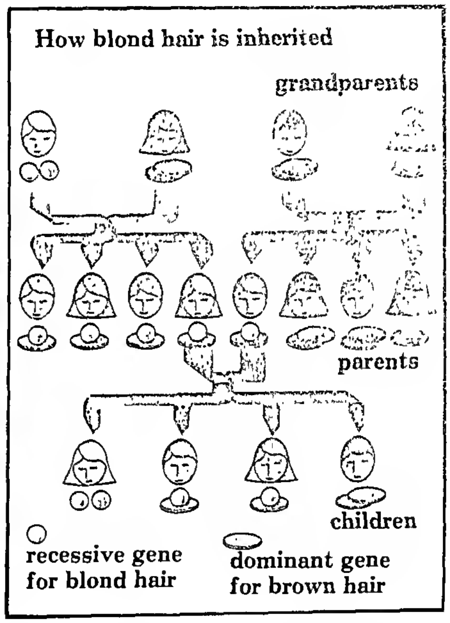
Genes

Genes are too tiny even to be seen under a microscope. But they are very big in importance. The way the genes rom our mother and those from our father come ogether decides everything about how we will look and behave. This means everything from the size of our ingers to the shape of our hips, from how gracefully we valk to how well we see, even from suffering bad ieadaches to having a split personality.

The genes in each homologous pair of chromosomes control the same characteristic. For example, if the 10th gene of one pair has to do with the color of the hair, the 10th gene of the other pair will also be concerned with hair color. Let us look at what happens if the 10th gene of the pair, which came from the mother, carries the code for dark hair and the 10th gene of the pair coming from the father carries instructions for light hair. The child of this couple will have dark hair, because the gene for dark hair is dominant. A dominant gene can make the feature it is carrying appear in a person even if there is only one in the paired chromosome.

In contrast, if the genes from both parents carry the message for light hair, the child will have light hair. The gene for this color is recessive, but when two recessive genes come together, the characteristic they carry in common will show up in the child.

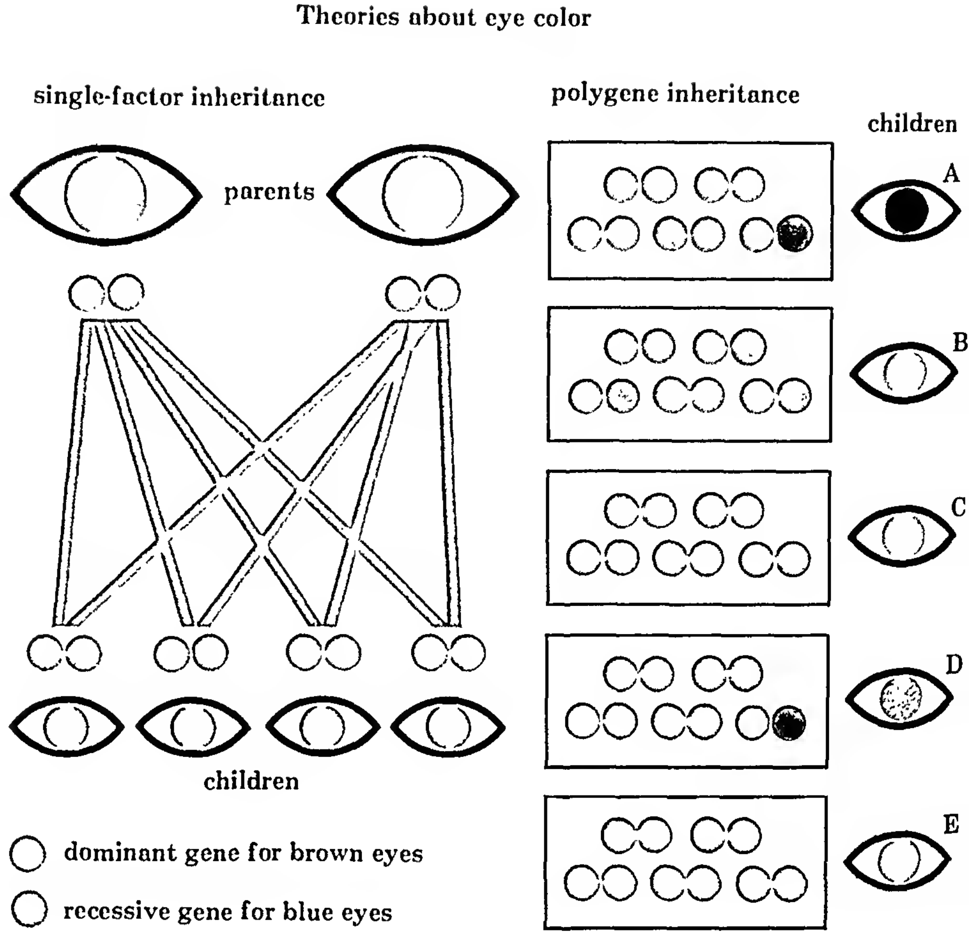
There is a very wide range in intelligence, talent, longevity (living a long life), height and weight. Geneticists now think that such characteristics are controlled by polygenes instead of a pair of genes. A



Above: This diagram shows how a blond child inherits this hair color from his or her ancestors.

Left: Parents with dark hair may each have a recessive gene for light hair. In this case, they could very likely have a blond child.

Right: These two diagrams depict two theories about how the color of eyes is passed on. The single-factor theory of heredity says that brown-eyed parents will usually have children with brown eyes, but might have a blue-eyed child if both the mother and father have recessive genes for blue eyes. The polygene theory says that a group of genes acting together control eye color. Parents with blue eyes will have blue-eyed children (E), but parents with other eye colors could have children with a number of different eye colors. Which color cannot be predicted because there is much variation possible when more genes are interacting with one another (A, B, C, and D).



polygene is a group of genes that act together, with each gene giving a bit of itself to make up the final feature.

Dominance

Most of the characteristics that we call normal are controlled by dominant genes. That is why most of us have ten toes, why most people's blood clots when necessary, and why most hear all right. Strangely enough, however, normality is not always dominant. It is surprising which abnormalities are dominant.

For example, the gene that can produce hypertension (high blood pressure) or migraine headaches is dominant. So is the gene that makes people nervous in temperament (make-up of your nature), that produces the rare RH blood group, and that makes people near or farsighted.

Certain abnormalities are known to happen when two recessive genes combine. One of these is albinism, which is a lack of pigmentation in the skin. It makes a person look almost totally white all over, with colorless hair and pinkish eyes. Another case like this is cystic fibrosis, a disease affecting digestion and breathing. There are two inherited disorders that almost always happen to males only, and these are color blindness and hemophilia (a condition in which the blood will not clot).

The recessive genes for color blindness are carried only on the X chromosome of the sex cell. Such inheritance is called sex-linked. A woman has two chromosomes, but only one of them will carry the disease-causing gene if she inherited it. The other X chromosome will carry a normal gene which will dominate and keep the abnormal gene from causing the disease. Thus the woman would not be a victim of the disease but a carrier. A man, you will recall, has one X chromosome (from his mother) plus a Y chromosome (from his father). If his one X chromosome has the disease-causing gene, he will be a hemophiliac or color blind. This is because the recessive gene can express itself since there is no other X chromosome gene to dominate.

Inherited disorders

As we have seen, some abnormal characteristics are dominant and some can be inherited as the result of the same recessive genes being present in both parents. It is fortunate, if sad, that children who inherit extremely serious disorders do not often live long enough to have children and pass the problem on.

On the other hand, some of the royal families in

history have passed on terrible abnormalities for many generations. One well-known example is Emperor Maximilian I (1459-1519) of what is now Germany. He and his family had the disease known as acrocephaly, which makes the lower jaw protrude so much that the lower teeth are in front of the upper ones. The mouth also often hangs open uncontrollably.

Many royal males of Europe suffered from hemophilia. The son of the last czar of Russia was one of them. The main reason for this pattern of heredity was that the royalty of Europe intermarried with cousins for generation after generation. It is a fact of genetics that, if parents are blood relations such as cousins, there is more chance of them having the same recessive genes. This certainly explains the frequent characteristic of hemophilia in the male heirs of European monarchs.

Mutations

Let us go back to the process of meoisis, or cell division. When a cell divides, each new cell has to copy the chromosomes that are in the nucleus of the original cell. This is done by a complicated chemical action, and it is done millions of times with millions of cells. It is not hard to see that mistakes can happen.

Even a tiny error will change the message carried by the genes inside the chromosome, and this changed code will then be reproduced in all the cells of all the children from then on. This change is called mutation, and it is the only way that new genes can be produced.

Mutation was very important in the evolution of humans, because each new mutant helped make the change from a tiny one-celled organism to the complicated being we are today. Mutations happen at a very slow rate,which is why it took millions of years for human evolution.

Mutants can be created faster by chemicals and by RADIATION. The radiation from nuclear fallout is especially effective, and so particularly dangerous. Mutants are still being born in Japan more than 40 years after the first atomic bombs were dropped on Hiroshima and Nagasaki. This is a case of mutation being for the worse.

Some of the things that can go wrong during meiosis are that a piece of a chromosome will be left behind, a piece may be added onto a chromosome, or an extra chromosome may be added to the sex cell. Each of these errors brings some kind of mutation with it. If there is an extra 21st chromosome in the sex cell, a child is born with Down's syndrome (mongolism).

Heredity isn't everything

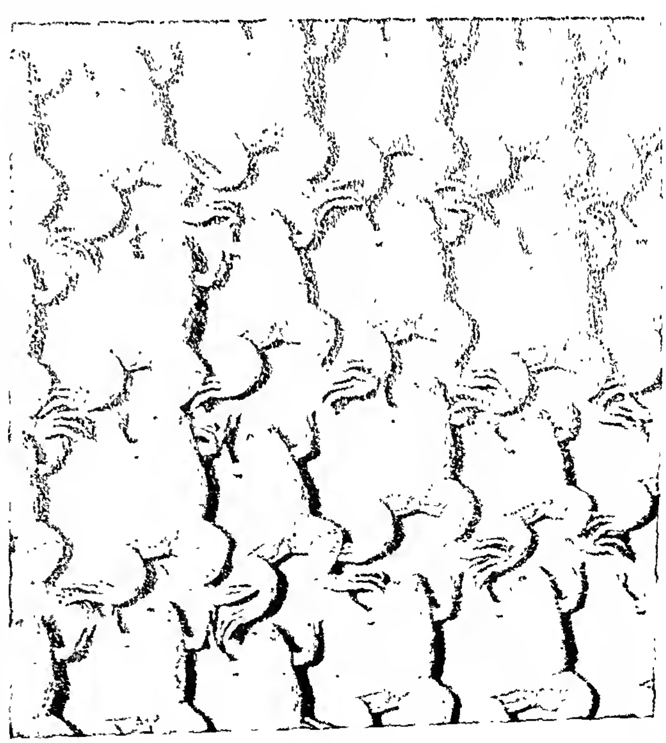
As we have seen, heredity gives us our outside appearance, our inside structure, and our invisible qualities such as intelligence, nervousness, and mental health. But other things can influence (have an effect on) what the genes have given us.

In the first place, there is a difference in the penetrance of a gene—that is, how much a gene can make its power felt in the person it is a part of. One person who inherits a finger defect for example, may suffer stiffness only in a single digit. Another person with the same disease may have severe stiffness in all 10 digits. Someone who inherits diabetes may just have to be careful of diet. Someone else may have to take high-dose insulin injections every day.

The world about us

The environment (family and cultural surroundings that influence a person) also acts upon heredity. For instance, the type and amount of food we eat can make us fat in spite of what our genes say we should be. Overeating makes anyone overweight. Being in the sun a great deal will make our skin darker—maybe even black—even if our parents are fair. In fact, geneticists say that black skin is a mutation that helped people live in the very hot sun of the tropics. The sons or daughters of parents who lived a long time may also enjoy longevity, but they may change the path of heredity and die young if they drink or smoke too much.

See also: CELLS, EVOLUTION, POPULATION GROWTH



Right: Geneticists created these test-tube frogs, all of them identical. They are called clones.

Geology

Geology is the study of the earth and how it changes. Some geologists study minerals, rocks, and rock structures. Others are interested in earth history. Geology is a useful science. It enables us to make use of the many resources inside the earth.

Our planet earth is about 4500 million years old. But up until about 1680, most scholars thought it was only a few thousand years old. Archbishop James Ussher of Ireland (1581–1656) studied the Bible and worked out that the earth had been formed in 4004 BC. Many people thought that fossils were the remains of creatures drowned in the Biblical Flood, which they thought had occurred in 2348 BC.

A few early scholars, such as the brilliant Italian artist Leonardo da Vinci (1452–1515), did not accept such ideas. He believed that natural processes were responsible for fossils. He also understood that rivers wear out the valleys they occupy.

The birth of modern geology

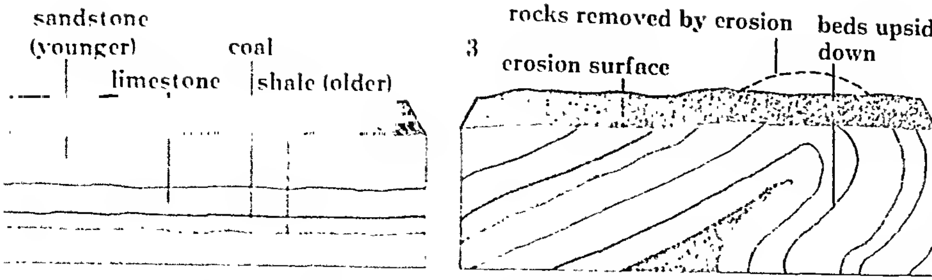
Geology is a young science. Modern geology dates from the work of a Scottish physician, James Hutton (1726–97), who put forward his ideas in a book, *Theory of the Earth.* He wrote that the land was always changing. Rivers and glaciers had worn out deep valleys and carried the loose material downhill. The worn material, including pebbles, sand and mud, piled up, layer upon layer, to form new sedimentary rocks (rocks, such as sandstone which are composed of sediments). He also understood that IGNEOUS rocks, such as basalt and granite, were formed when molten rock cooled and hardened. Hutton realized that the earth must have had a very long history for all these rock-forming processes to have occurred.

Hutton put forward the important idea that the processes that were changing the land at present had always been operating. "The present," he said, "is the key to the past." Hutton's ideas were not accepted at first. But another Scot, Sir Charles Lyell (1797–1875), supported Hutton in his *Principles of Geology*, which appeared in the 1830s. Lyell convinced people of the truth of Hutton's ideas and greatly influenced the naturalist Charles Darwin.

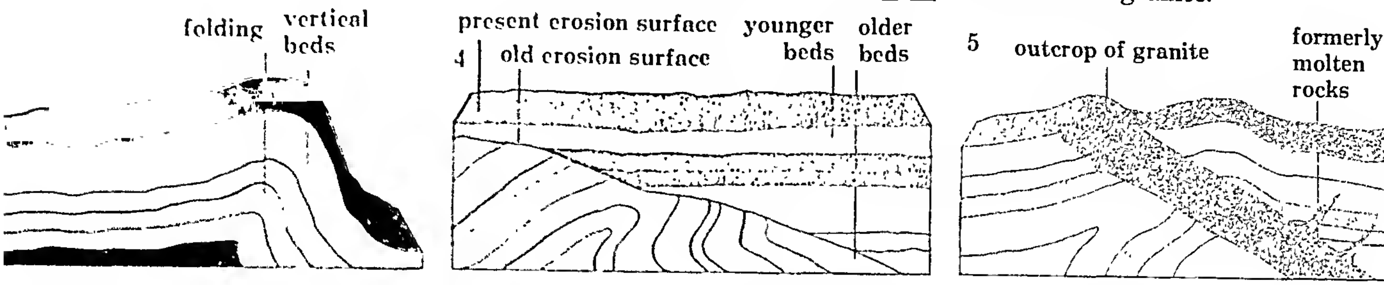
Geology in the 19th century

A British engineer, William Smith (1769–1839), made other important contributions to geology. While working on the building of canals, he studied the fossils he found in the rocks. He noticed that some fossils occurred in many layers of rock, while others were found in only one layer. Fossils found in only one layer

Below left: In undisturbed rock layers, the younger layers are at the top and the older ones are below. In folded rocks (center) older rocks may overlie younger ones. When rocks are tilted vertically (right) the older rocks may be on the right or on the left.



Left and below:
Horizontal rock layers (1) may be folded (2). After erosion (3), the worn rocks may be covered by younger rocks (4). Molten rock forced into existing layers (5) hardens into granite.



are called ZONE or index fossils. Smith realized that rock layers containing zone fossils were all of the same age. Smith also understood that, in undisturbed sedimentary rocks, the younger rocks are always on top of older rocks. His ideas enabled him to classify rocks according to their age. In 1815, he published a geological map of the rocks which lie under the soil in southern England. It was the first map of its kind.

Geology advanced quickly in the 19th century. A Swiss professor, Louis Agassiz (1807–73), studied the work of ice in molding the land. John Wesley Powell (1834–1902), who explored the Grand Canyon, suggested that the forces of erosion would eventually wear down the land to a base level. This idea was developed by another American, William Morris Davis (1850–1934), who suggested that landscapes pass through a cycle of erosion. They end up as a peneplain, which means "almost a plain." But modern geologists believe that such cycles are rarely completed. Movements inside the earth, changes in climate, and other factors interrupt them.

In 1895, the discovery of RADIOACTIVITY finally provided a method for dating rock layers. The earth was shown not to be millions of years old, as some thought, but thousands of millions of years old. Radioactive dating also made it possible to find the ages of the eras and periods in earth history.

Continents adrift

In the early 20th century, a German scientist, Alfred Wegener (1880–1930), suggested that the continents had once been joined together in one huge land mass. But, he argued, this land mass had broken up and the continents had drifted apart. Wegener's ideas were rejected in his lifetime. But studies of the ocean floor in the 1950s and 1960s helped to prove the theory of continental drift.

Scientists now believe that the earth's crust is divided into large blocks, called plates, on which the continents rest. Beneath the earth's thin crust, in the hot upper mantle, are fluid rocks that move in slow currents. These currents carry the plates around like rafts in water. This theory helps to explain how mountains are formed, and why earthquakes and volcanic eruptions occur.

Physical geology

There are two main branches of geology: physical and historical geology. Physical geology includes the study of the many minerals and rocks in the earth's crust. The study of minerals is called mineralogy, and the study of rocks is petrology. A specialized branch of mineralogy is crystallography, which is concerned with the crystals formed by minerals.

Structural geology is the study of rock structures. Most sedimentary rocks form in nearly level layers, called strata (singular, stratum). But movements inside the earth bend strata into upfolds called anticlines, or downfolds, called synclines. The massive forces within the earth also break the strata to produce enormous cracks, called faults. The study of these and other features is important in prospecting, the scientific search for valuable resources inside the earth.

Geochemistry, which combines chemistry and geology, is also important in prospecting. Geochemists sometimes locate mineral deposits by analyzing soil, water and plants. Important in the hunt for oil and natural gas is geophysics, which combines physics and geology. A major branch of geophysics is seismology, the study of earthquakes. Vulcanology is the study of volcanoes.

Natural forces, including the weather, running water, bodies of ice, sea waves, and the wind, constantly change the earth's surface. These forces wear away (erode) rocks and transport the worn material only to dump it elsewhere. Geomorphology is the study of how

the forces of erosion and earth movements create landscapes from rocks of varying hardness.

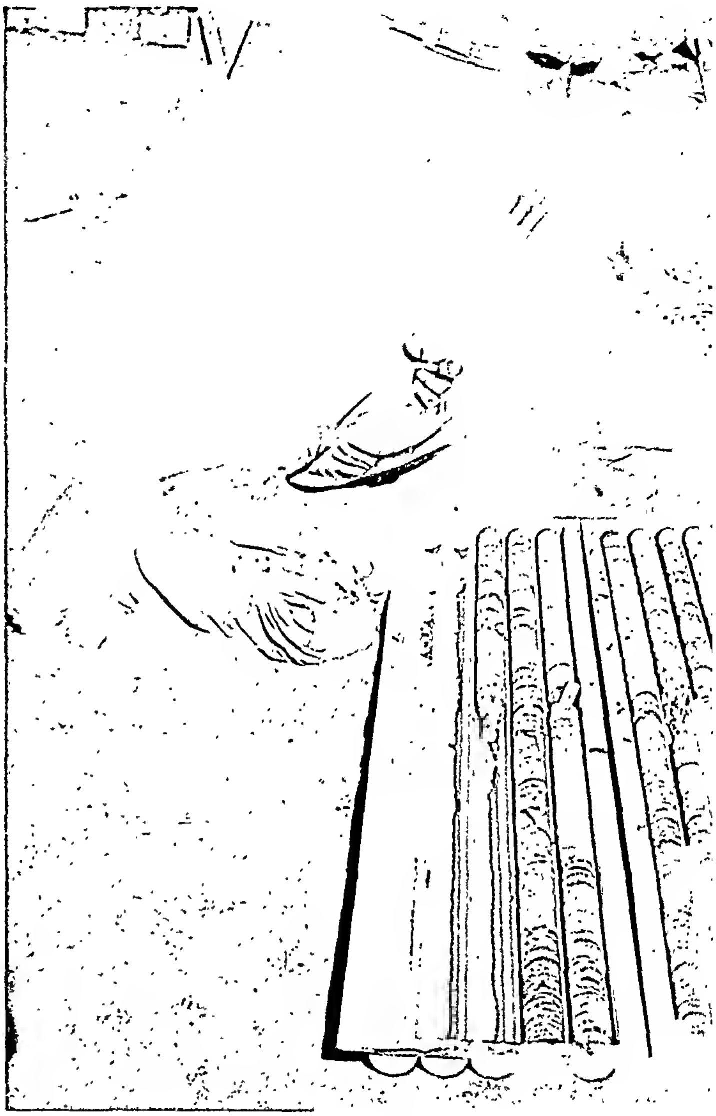
Besides rocks and minerals, the earth's crust also contains water. Geologists are concerned with the location of water and water supply, a branch of the study of hydrology. Physical geology is also an important aspect of the study of soils (pedology), and the study of the oceans (oceanography).

Historical geology

Historical geology is concerned with the history of the earth through geological time. Stratigraphy is the study of the sequence of rock strata and their place in earth history. Fossils, evidence of ancient life, occur in many sedimentary rocks. The study of fossils (paleontology) is important. It contributes much to our understanding of evolution.

The nature of rock strata and the fossils they contain gives clues to the changing climates of the past. For example, coal beds have been found in Antarctica. Antarctica is now covered mostly by ice, and the plants from which coal formed could not grow there. Clearly, Antarctica once had a much warmer climate than it does today, and only 12,000 years ago much of North America and northern Europe was hidden under ice. The northern continents have enjoyed a temperate climate only in the past 10,000 years. The study of past climates is called paleoclimatology. It is important because we know that climates are still changing. Paleoclimatologists are trying to find clues as to whether the northern hemisphere is likely to enter another Ice Age in the near future.

The study of the changing geography of the earth and the movements of land masses is called paleogeography. This is concerned with the relationships between ancient animal and plant life and the conditions in which they existed.



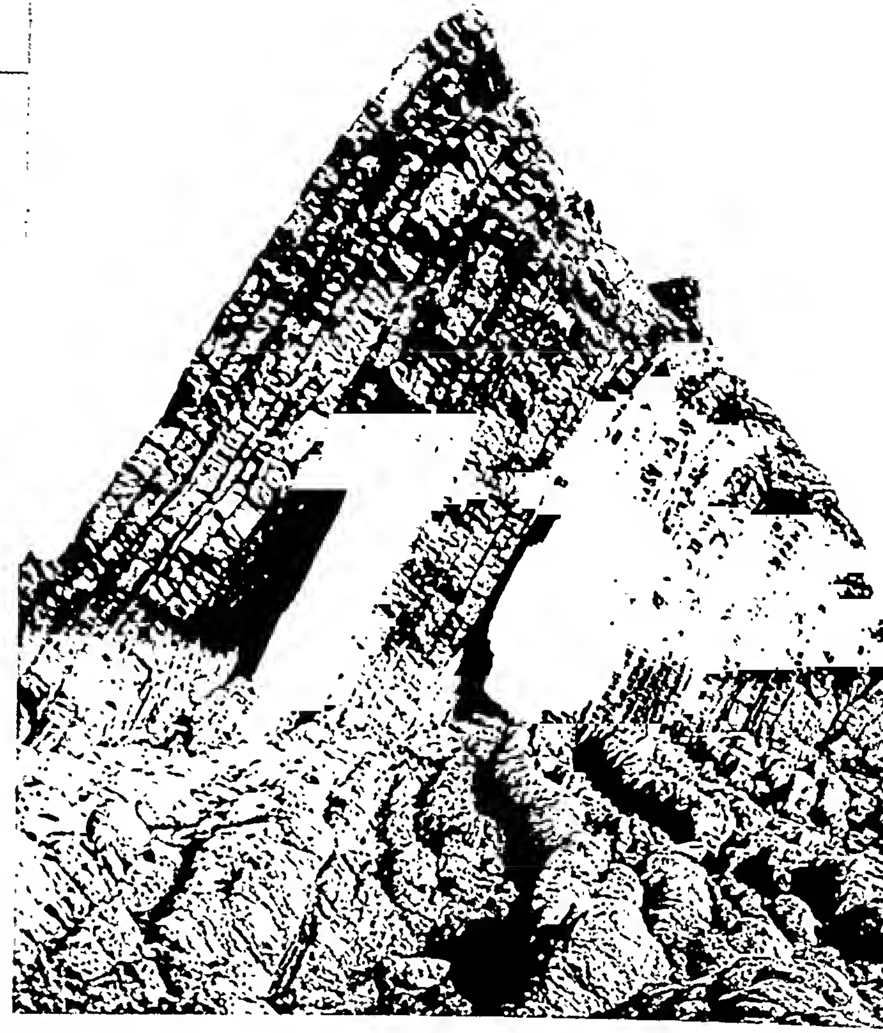
Geological techniques

One important technique in geology is the study of small pieces of rock. Specimens of rock are collected in several ways. Pieces from the surface are chipped away with a strong geological hammer. (Ordinary hammers are not used because their heads may break off when striking hard rock.) Other rock specimens are obtained from boreholes or coring tubes. Coring tubes are vertical, hollow tubes which are dropped from a ship. When they hit the seabed, the force of the impact rams the tube into the rock. The corer is hauled back to the ship and the sample is removed.

All rocks are made up of minerals. Geologists have classified nearly 3000. The minerals in a rock sample can be identified in many ways. Some are recognizable because of their hardness, color, cleavage (the way they split apart), their transparency or their crystals. In a laboratory, rock samples can be chemically analyzed, or studied under microscopes. Thin sections of rock, only 30 microns (about one-thousandth of a millimeter) thick, can be viewed under a powerful microscope. In this way, geologists get clues about the nature of the rock and how it was formed. Some rocks contain fossils of tiny animals and plants which cannot be seen with the naked eye. But they can be identified under a microscope. Their presence may indicate the age of the rock. They may also be a clue to the presence of oil or natural gas, substances that were formed from the remains of tiny plants and animals.

Dating rocks

Rocks that contain traces of radioactive elements are dated by geochemists. Today, geochemists use large machines called mass spectrometers to measure the age of rock samples. Radioactive elements break down (decay) at a constant rate, producing a stable (non-radioactive) end product. For example, the radioactive



Left: These rock specimens taken with a corer reveal the nature of the rock layers beneath the surface.

Above: These layers of shale and sandstone have been tilted upward by tremendous forces inside the earth.

element uranium breaks down to form the stable metal, lead. In 713 million years, half of the uranium atoms change into lead atoms. The mass spectrometer measures how many lead atoms there are in a sample of uranium. From this measurement, they can work out the age of the sample.

Economic geology

Many geologists work as prospectors. They search for metals and other minerals, fossil fuels such as coal, oil and natural gas, radioactive substances including uranium, underground reserves of water, and sources of stone for building.

Geologists first map the rocks that appear on the surface and collect as much information as possible about the rock structures beneath the surface. They are aided in this by geophysical techniques. Aerial photographs and pictures taken from satellites circling the earth also provide much information for geologists.

The information collected by geologists is of great importance to civil engineers who want to choose sites for bridges, dams or skyscrapers. The geologists are able to tell whether the foundations for these structures are secure. Other geologists work in mining and help to find the cheapest and safest routes for tunnels.

Since the start of the space age, some geologists have become interested in the geology of space. They are especially interested in the moon and also in the planets. They are aided in their work because meteorites (fragments of rock from space) occasionally land on the surface of our planet.

See also: EARTH, EARTHQUAKE, EVOLUTION, FOSSILS, ICE AGES, MINERALS, MOUNTAINS, OCEANOGRAPHY, PLATE TECTONICS, ROCKS, SOIL, VOLCANOES, WATER SUPPLY, WEATHERING AND EROSION, WIND EROSION

Geomorphology

The land around us is constantly changing. Natural forces are always wearing down the land, reducing high mountains to low plains. Earthquakes and volcanic eruptions also change the land. Study of the earth's surface and how it changes is called geomorphology.

Even as tremendous forces inside the earth push rocks upward into towering mountain ranges, natural processes wear them down. Forces that act on the earth's surface include chemical changes caused by rain, which can dissolve rocks or make them crumble. Rapid heating by the sun or frost action can split and shatter tough rocks. In mountain areas, loose rock fragments tumble downhill because of gravity. Long glaciers and mountain streams transport the broken rocks beyond the mountains toward the sea. Glaciers, rivers, winds in dry regions, and the restless waves along coastlines also mold surfaces by erosion, transportation and deposition. Deposition is the dumping of rock fragments, such as sand. Over many years, layers of these fragments are compressed into new rocks, such as sandstones.

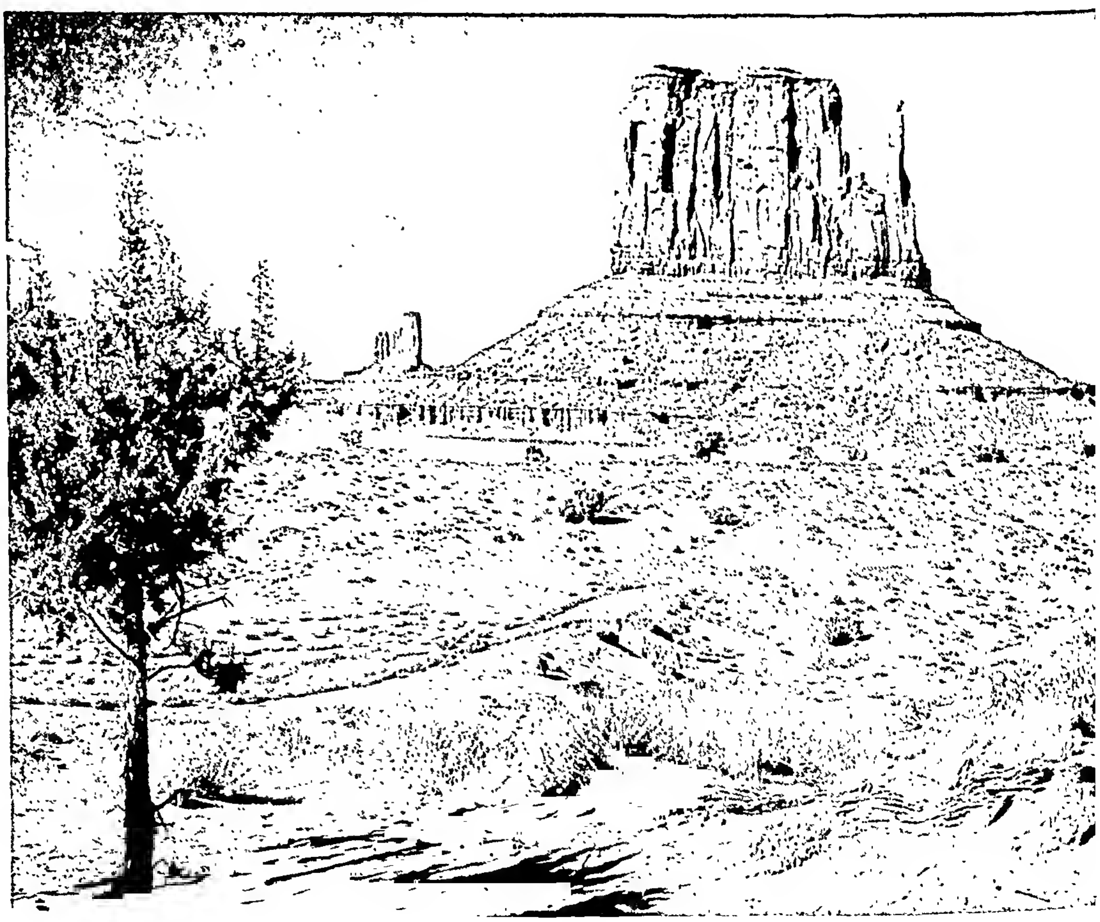
Internal forces that also mold the land originate inside the earth. These forces include earthquakes, t movements of rocks along faults (large crack volcanic eruptions, and the uplifting of rocks into fo and block mountains.

Geology and land formation

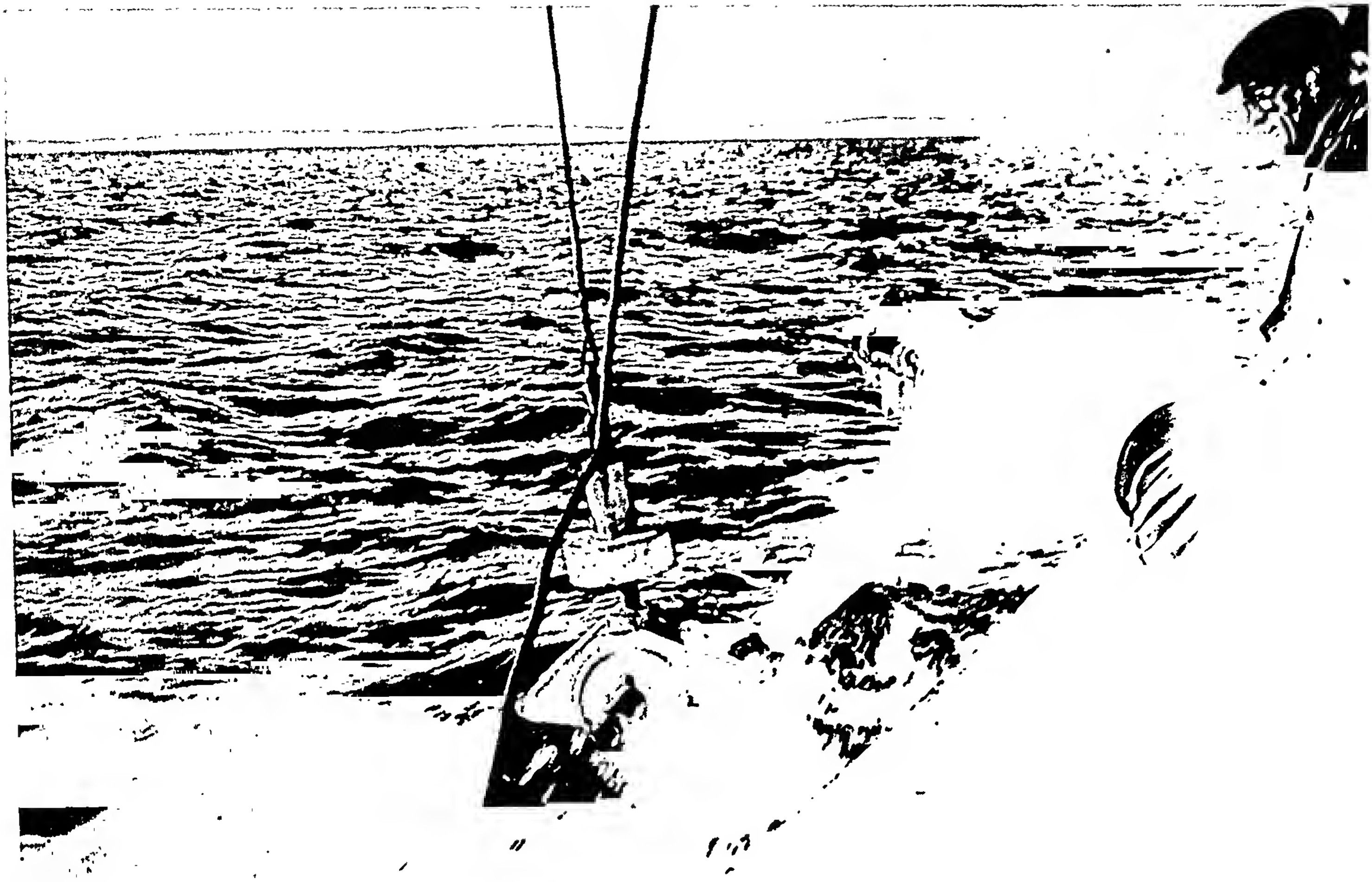
The formation of any region may be largely determin by natural forces. For example, the glaciated highlan have been largely shaped by glaciers.

But the nature of the rocks in any area also affec the shape of that land. Some rocks are hard and resi erosion, while others are quickly worn away. F example, hard rocks along coasts form headlands, whi softer rocks between headlands are worn back to for bays. Limestone is a rock that dissolves in rain wate Rain water is a weak acid, because it contains son dissolved carbon dioxide, and it enlarges cracks in t surface of limestone. The water seeps into these crack wearing out deep pits and caves under the ground. T action of rain water produces typical limestone, c karst, formations.

See also: EARTHQUAKE, GLACIATION, MOUNTAINS, PLATE TECTONICS, SEA EROSION, VOLCANOES, WIND EROSION



Right: Monument Valley in Utah and Arizona is familiar to us from many western movies. The valley contains many steep-sided hills. These hills are capped with layers of hard rocks that rest on and protect softer rocks beneath them. Mesas are large, table-like hills with flat tops. They are often formed when rivers cut canyons into flat land surfaces. After the river has done its work, the mesas are all that is left of the old land surface. But the mesas are also gradually worn down, often by wind erosion. They are changed into smaller, jagged hills called buttes.



Above: Mud samplers pick up surface sediment and rocks from the seabed. The samples are automatically triggered when they hit the bottom.

Measuring magnetism

Geophysicists are also interested in the earth's magnetism and they use instruments called magnetometers to record local variations. Such studies are especially useful in pinpointing areas which are rich in valuable metals.

The earth has two magnetic poles. When molten rock cools and hardens, iron minerals are magnetized and aligned in a north–south direction. The study of rock samples containing magnetized particles has shown that the earth's magnetism periodically changes direction. The north and south magnetic poles are then interchanged, although no one is sure how these reversals occur. But the existence of magnetized particles helps geophysicists to trace changes in the earth's crust.

The study of paleomagnetism (ancient magnetism) has shown that there are broad strips of rock containing particles magnetized in opposite directions on either side of long mountain ranges in the oceans, called oceanic ridges.

Continental drift

The study of paleomagnetism has been important in establishing the theory of continental drift. This theory suggests, for example, that North America was once joined to Europe, and South America to Africa. Geophysicists have shown that these land masses have been separated because the Atlantic Ocean has been widened along the mid-Atlantic ridge. Beneath this ridge, molten rock is welling upward. This molten rock hardens along the ridge to form strip after strip of new crustal rock.

Plate tectonics

As a result, the rocks become older to both the east and the west of the ridge. The mechanism by which oceans are being widened is called plate tectonics. Plates are large blocks of the earth's crust that are being moved around. In the deep ocean trenches, plate edges are being pushed downward and melted.

See also: EARTH, EARTHQUAKE, GRAVITY, MAGNETISM, OCEANOGRAPHY, OIL EXPLORATION, PLATE TECTONICS, SEISMOLOGY

Glaciation

Ice sheets and glaciers wear away the land and mold spectacular scenery. This process is called glaciation. Ice now covers about 10 percent of the earth's land surface. But during the last Ice Age, it covered almost 30 percent of land areas, spreading as far south as New Jersey and Illinois.

Today, there are two vast ice sheets. The largest covers most of the continent of Antarctica and the other most of Greenland. There are also ice caps in northern Canada, Iceland, Spitzbergen and other parts of Norway. Ice sheets and glaciers move slowly outward and downhill under pressure and the force of gravity. Near coastlines, the ice often forms valley glaciers, the ends of which break off to form icebergs. There are also valley or mountain glaciers in highland regions throughout the world, except in Australia.

How glaciers form

Ice forms above the permanent snow line, where winter snowfall does not melt completely in summer. At the poles, the permanent snow line is at sea level. At the equator, it is about 17,000 to 18,000 feet (5180-5490 meters) above sea level.

Fresh snow is light and easily disturbed. But as layer upon layer of snow piles up in mountain hollows, sometimes supplemented by avalanches, loose snowflakes are pressed together. In some areas, surface snow melts in summer. The meltwater trickles downward and refreezes. This process further compacts the snow. Compacted snow is called by the German word *firn* or the French *névé.* Compacted snow is white, but as the air is gradually squeezed out, the firn changes into a clear blue glacier ice, made up of interlocking ice crystals.

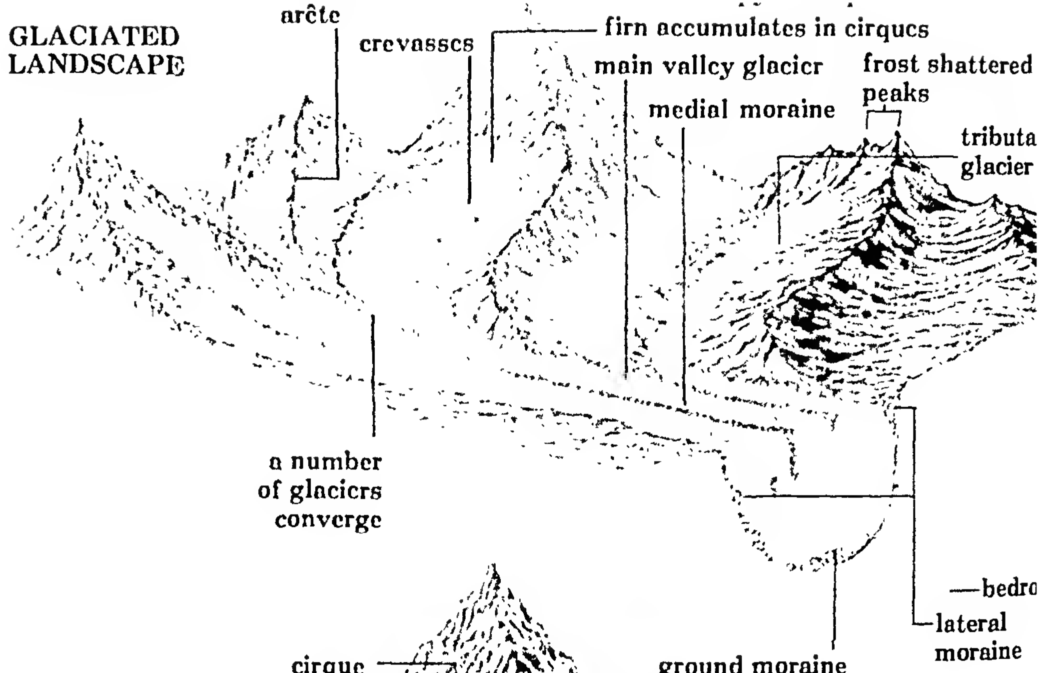
Glacier flow

Ice formed in mountain hollows eventually spills outward and flows down valleys in the mountainside. Narrow glaciers usually merge with others flowing from neighboring valleys to form wide glaciers. The end of a glacier, called the snout, is often far below the permanent snow line.

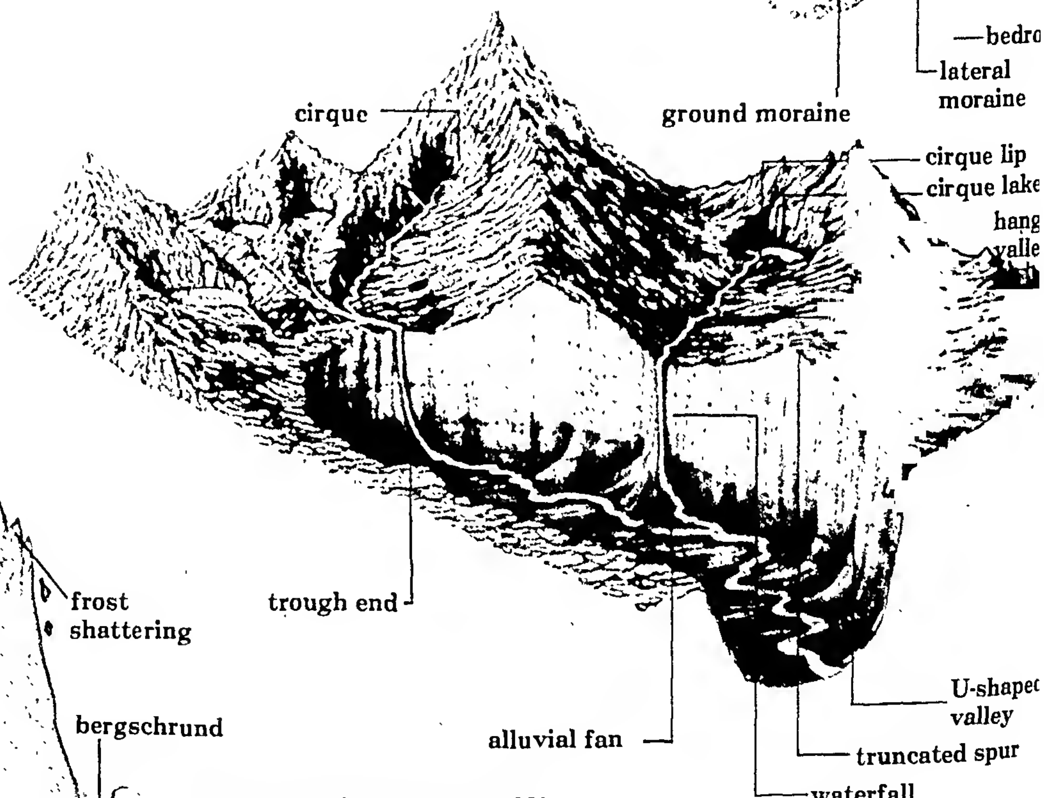
The flow of glaciers is caused by the special properties of ice. Pressure and stress in bodies of ice lower the temperature at which ice melts. As a result, thin films of water form in the ice because of the pressure and these wet planes enable ice crystals to slide over each other. Some glaciers in temperate regions are called wet-based. This is because they have a thin layer of water at the bottom of the ice which is at pressure melting point (the lower melting point of ice under great pressure). The ice can slide faster over the wet-based than over dry-based ice bodies.

For example, in Antarctica, the base of the ice is usually below freezing point. This means that it is frozen to the rock and no water can exist at its base. In Antarctica, the movement of the ice is only a few feet a

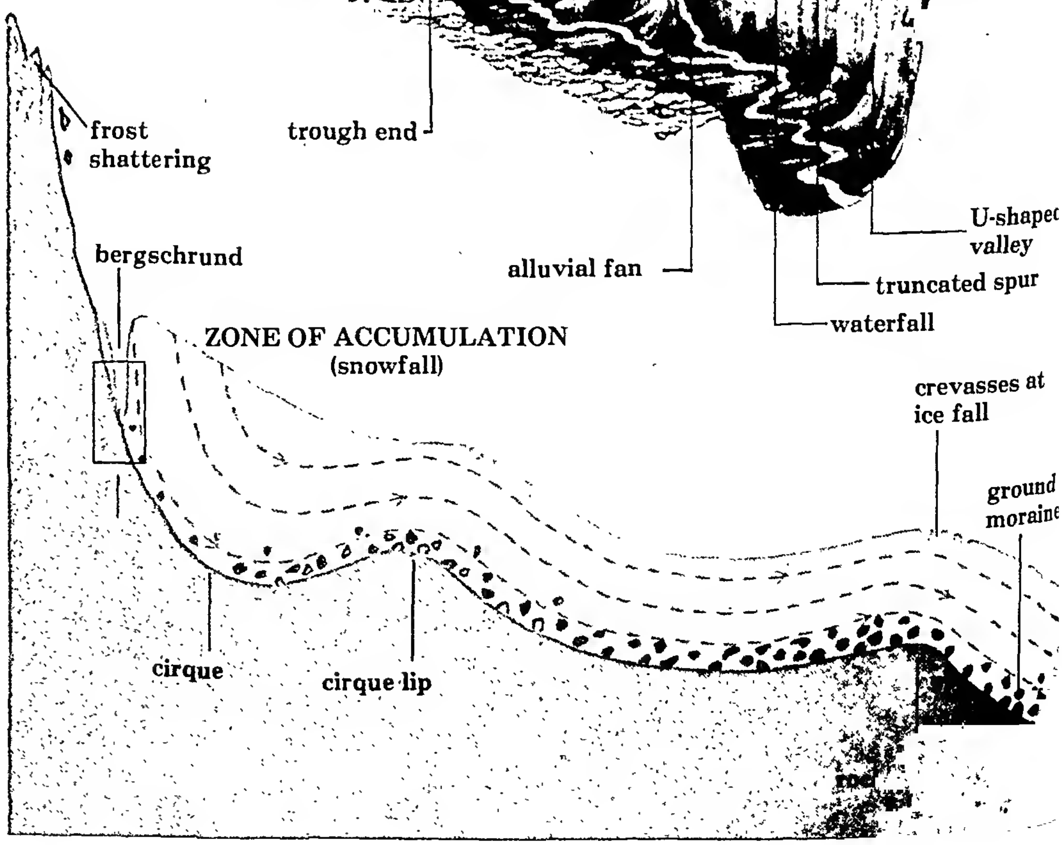
Left: New Zealand's Southern Alps once contained far more snowfields and longer glaciers than they do today. The glaciers flowed down valleys, gouging out deep, straight, U-shaped valleys. After the glaciers melted, these impressive, steep-sided valleys were exposed. The jagged peaks above the valleys were formed by both ice and frost action.



Right: The diagram shows a mountain landscape covered by snow and ice. Snow accumulates in basins, called cirques, and is compacted into a firn or névé, which is finally turned into glacier ice. The glacier ice flows downhill. Several glaciers merge to form a large valley glacier.



Right: After the ice has melted, the power of the glaciers is revealed in such features as armchair-shaped cirques and U-shaped valleys. Side valleys are left much higher than the over-deepened main valley. They are called hanging valleys. From them waterfalls plunge into the main valley.



Right: The section shows features of a valley glacier. Snow is compacted into ice in the cirque. Near the head of the cirque is a bergschrund, a deep crevasse. Frost-shattered rocks fall into this crevasse and are frozen into the ice to become ground moraine. Crevasses also form as the glacier flows over the uneven valley floor.

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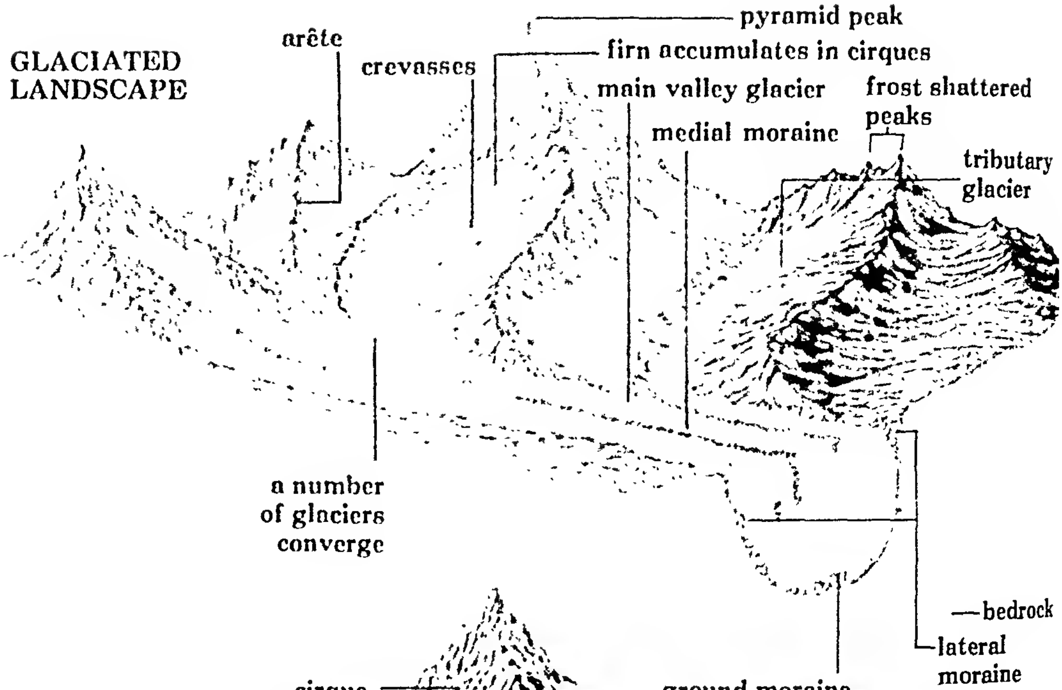

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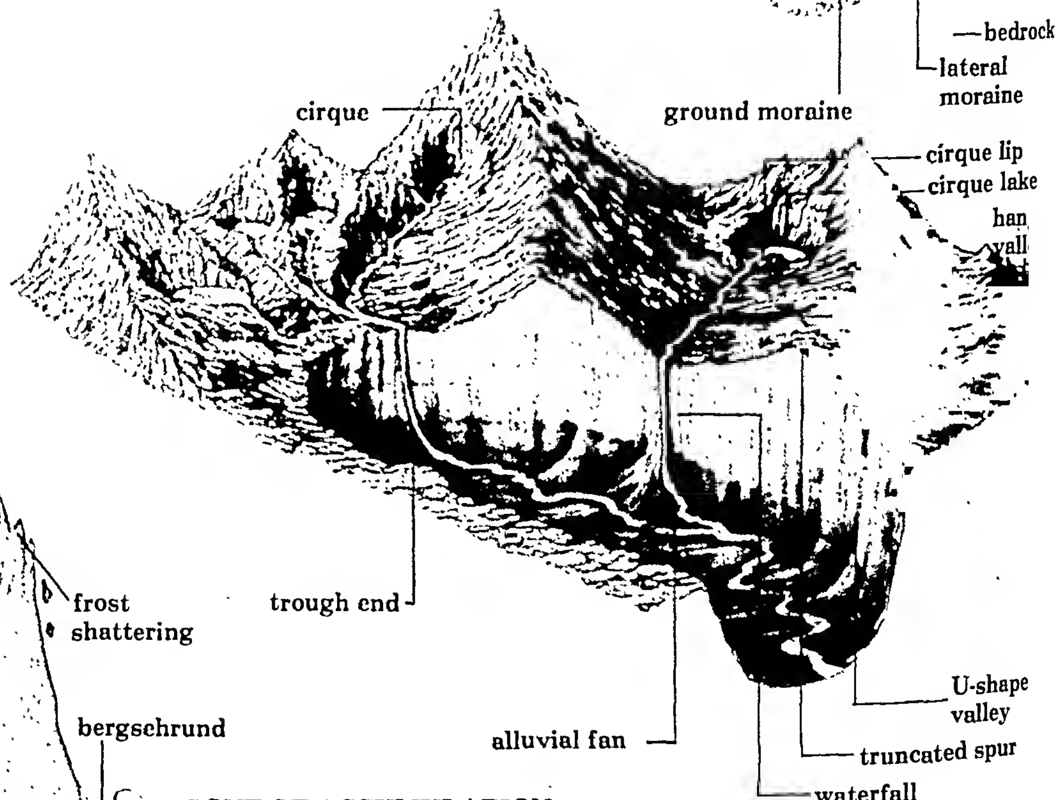

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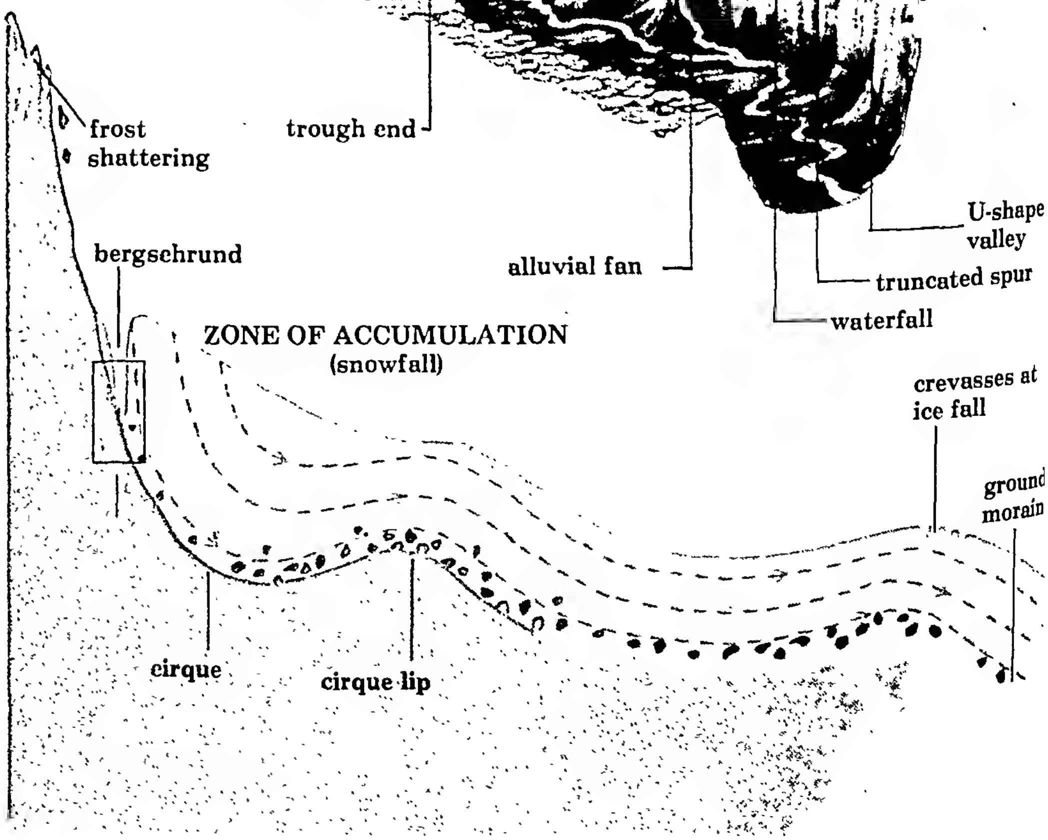


year, while wet-based glaciers move much faster. For example, in 1863, three mountaineers were hurled into a deep crevasse in the Glacier des Bossons, on the slopes of Mont Blanc in France. Some 43 years later, bits of their bodies and equipment emerged at the snout of the glacier. They had been carried about two miles (3.2 kilometers) at a rate of 240 feet (73 meters) a year.

On the other hand, an avalanche on the source of Alaska's Black Rapid's Glacier made it advance about four miles (6.4 kilometers) between September 1936 and February 1937. On some days, it advanced by more than 200 feet (61 meters) in 24 hours.

Features of glaciers

As a glacier moves downward, the surface starts to split and crack—probably because of movements in the ice—and openings called crevasses are formed. Crevasses are often filled with snow and are then a danger to climbers. Some crevasses develop across a glacier at points where the slope changes. Other marginal crevasses form because the ice in the center of the glacier moves faster than the ice that drags against the valley walls. Sometimes, the surface is broken into a jumble of crevasses and séracs (icy pinnacles).

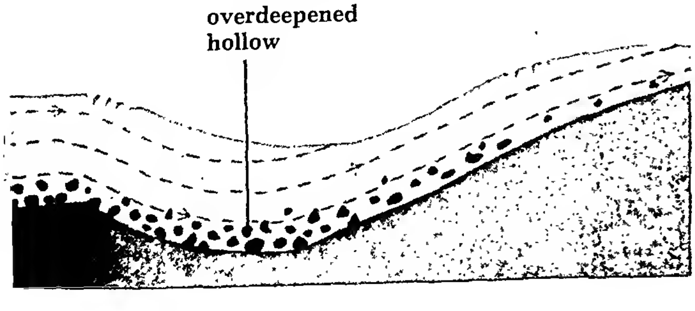
At the top of a firn field is a special kind of crevasse, called a bergschrund. This yawning hole develops as the ice pulls away from the rear wall. Bits of frost-shattered rock tumble into the bergschrund and other crevasses and become embedded in the ice.

Rocky material carried by glaciers is called moraine. Moraine also litters the surface of the ice. Rocks that tumble down mountain slopes and fall on the edges of glaciers are called marginal moraine. When two glaciers unite, two marginal moraines merge to form a medial moraine.

Glacial erosion

During its journey, a glacier erodes (wears away) the underlying rocks in several ways. First, the rocks frozen into the base and sides of a glacier give "teeth" to the ice, making it much like a huge, flexible file. The glacier, therefore, scrapes, polishes and scratches the underlying rocks. Long scratches, called striations, can often be seen on rocks in glaciated areas.

The weight of the ice also crushes and breaks up underlying rocks, while plucking occurs. As the ice freezes around jointed and faulted rocks, it pulls them away as the glacier moves, a process called plucking. The effect of glacial erosion is especially marked when glaciers move down V-shaped river valleys. They then wear out deep, trough-like U-shaped valleys with flattish floors and steep sides. Tributary valleys alongside a glacier, which are not deepened to the same extent, are left "hanging" above the main valley. When the glacier melts, rivers flowing from hanging valleys often plunge into the main valley in spectacular waterfalls—such as those in Yosemite National Park, California. U-shaped valleys near the sea are often flooded after the ice has melted and form deep sea inlets called fjords.



Cirques

Other features of glaciated earth surfaces include armchair-shaped hollows in mountain regions called cirques. These hollows were once places where glacier ice formed. But after the ice disappeared, it left behind steep-sided basins with walls smoothed by ice-plucking, and overdeepened bottoms which were worn out as the ice advanced. Cirques often contain lakes, called tarns.

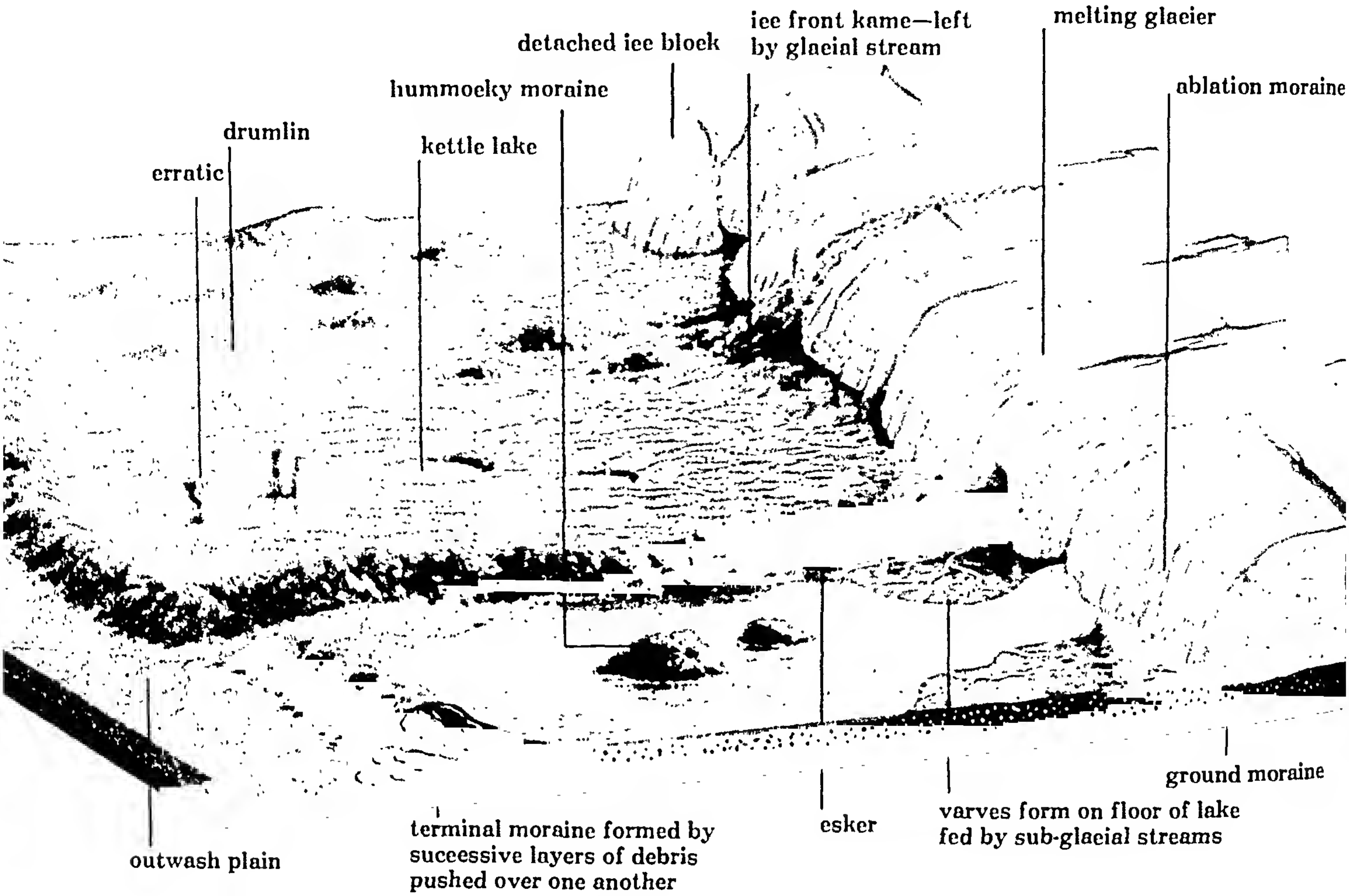
Often two cirques lie back to back. The erosion of the walls of the hollows creates knife-edged ridges, called arêtes, between them. When three or more cirques form back to back, the point at which they all meet becomes a pyramidal peak, or horn, such as the Matterhorn in the Swiss Alps.

Streamlined land forms

The moving ice may mold hummocks or small hills into streamlined land forms, called roches moutonnées. The upstream side of these features is smooth and often marked with striations. But the downstream side is jagged, because of ice-plucking. If a glacier meets a tough feature, such as the neck of an ancient volcano, it wears away resistant rocks on the upstream side, and then flows over the obstruction. Finally it dumps the eroded rocks on the downstream side. This feature is a crag-and-tail.

Glacial deposition

Glacial erosion occurs mainly in upland regions. The load of moraine worn by the glaciers and carried by them to distant lowlands ranges from large boulders to rock "flour." Rock flour is the name for fine material crushed and ground by the moving ice. The most common type of glacial deposit is called till or boulder clay, a term which well describes its varied composition. Boulder clay is sometimes dumped in hummocks, which are then rounded and elongated in the direction of the ice flow by glaciers. These hummocks are called drumlins.



Above: Moraine carried by glaciers is dumped near the end of the glacier, creating a variety of landforms. Large amounts of moraine are carried by streams of meltwater.

Massive boulders transported by glaciers are called erratics. They are recognizable, because the rocks in the bolders often differ from the rocks on which the bolders rest. In some northern states, such as Minnesota and South Dakota, erratics are common. They were once a serious obstacle to farmers.

At the snout of a stationary glacier, the load of material in the ice is dumped to form a ridge called a terminal moraine. It is often possible to identify a series of terminal moraines in glaciated country. Each of them marks a stage in the retreat of the glaciers and ice sheets of the last Ice Age. Terminal moraines often divert or block rivers whose waters accumulate in lakes. Other lakes form in ice-scoured basins when the ice melts. In fact, the presence of many lakes in a region may indicate recent glaciation. For example, Finland has 55,000 lakes which occupy moraine-dammed or ice-scoured basins.

Glaciofluvial deposits

Glaciofluvial deposits, or drift, are carried by streams of meltwater coming from a glacier or ice sheet. For example, eskers are narrow ridges that snake across the land. Most eskers were formed by streams that tunneled beneath the ice. Other features, called kames, are mounds of moraine. Many were formed by streams that emerged from high up on a stationary ice front. When they hit the ground, much of their load piled up in deltas or cones. Eskers and kames are features of glacial outwash plains. These plains are blanketed by glacial drift. Blocks of ice are sometimes left behind on these plains and may be covered by drift. When the ice melts, the surface becomes pitted with holes, which fill with water to become kettle lakes.

The study of features caused by glacial erosion and deposition helps us to understand how the surface formation is now being changed in snowcapped regions. It has also made it possible for geologists to identify the parts of the world which were blanketed by ice in the Ice Age.

See also: ICE AGES

Glands

The glands in our body are at work when we cry, when we blow our nose during a cold, when we sweat in the heat. One gland controls our size and the others give us our male or female sexual traits. These organs are important to our health in many ways.

Glands are organs that produce special substances for specific use by the body. These substances are called secretions.

Sometimes the glands send their secretions directly into the bloodstream, and then they are called endocrine glands. Sometimes they send the secretions through a duct, and then they are exocrine glands.

Endocrine glands

All the endocrine glands together form the body's hormone system. Hormones have something to do with almost every side of life, such as growth, sexual drive, reproduction, energy, and mental activity.

The pituitary gland is called the master gland because it has an effect on all the other ductless glands. Its own hormone affects growth, blood pressure, and certain muscles, among other things. The thyroid gland is important to metabolism (all the body's chemical changes) and breathing. The adrenal gland produces adrenalin for energy.

Exocrine glands

The salivary glands work in the mouth to begin breaking down food for digestion and the stomach and intestinal glands continue this process. The liver is the largest duct gland. One of its many functions is to produce the bile that assists in final digestion. The mammary glands (breasts) enable women to produce milk for feeding babies.

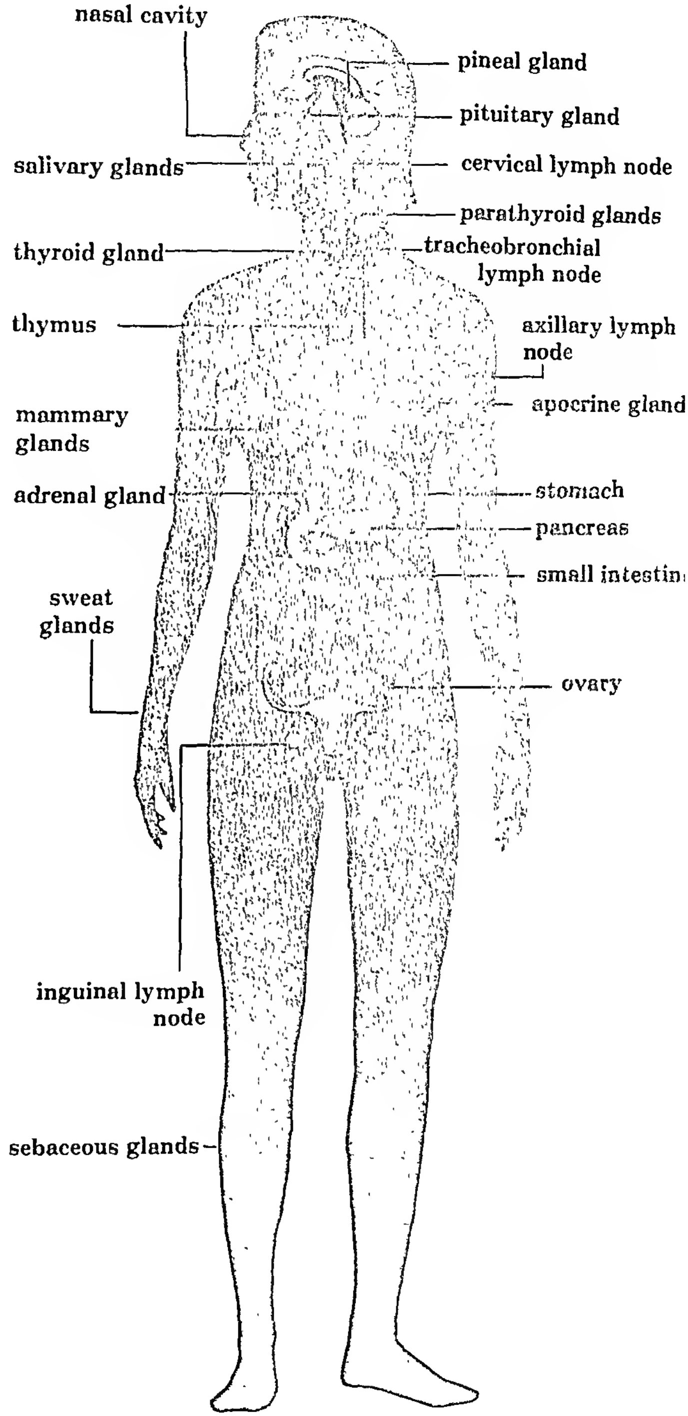
The pancreas is both endocrine and exocrine. As an endocrine gland, it produces insulin and glucagon. These help the body to use sugar properly. As an exocrine gland, the pancreas helps digestion by secretions to the small intestine.

Other glands

The thymus gland gets the body ready to fight infections. The sweat glands produce sweat and the lachrymal glands produce tears. The sebaceous glands produce a fatty lubricant (oiling aid) for the skin and hair. The mucous glands help protect the air passages from infection. When colds come, they work overtime and the excess mucus causes a runny nose.

There is a mystery gland called the pineal. It lies deep in the brain and no one yet knows what it does.

See also: BRAIN, DIGESTIVE SYSTEM, METABOLISM



Above: The glands of the body. There are many of these organs, all of which produce various substances that the body needs for healthy functioning. Lymph glands are unusual because they do not produce secretions. They are part of the body's defe— against infection.

Glass

It is almost impossible to imagine our world without glass. This useful and cheap material is used in every home, in industry and in science. Glass windows let in light but keep out the weather. We are surrounded by glass bottles, jars, electric light bulbs, mirrors, television picture tubes, and we can send telephone and television signals along fine glass fibers instead of copper wires.

Strangely enough, although it seems so hard, glass is not a solid. It is a molten liquid made of sand which has had limestone and soda added to it. When this molten liquid is cooled to ordinary temperatures, it becom very stiff and looks and behaves as if it is a solid. Gla is called a supercooled liquid. When it is cooled at t correct rate, it does not form crystals inside it and transparent.

We can actually see that glass is a liquid if we look very old windows. The glass in them tends to sa downward. Old Roman glass flasks found under ston are sometimes squashed flat rather than broken.

What is glass made of?

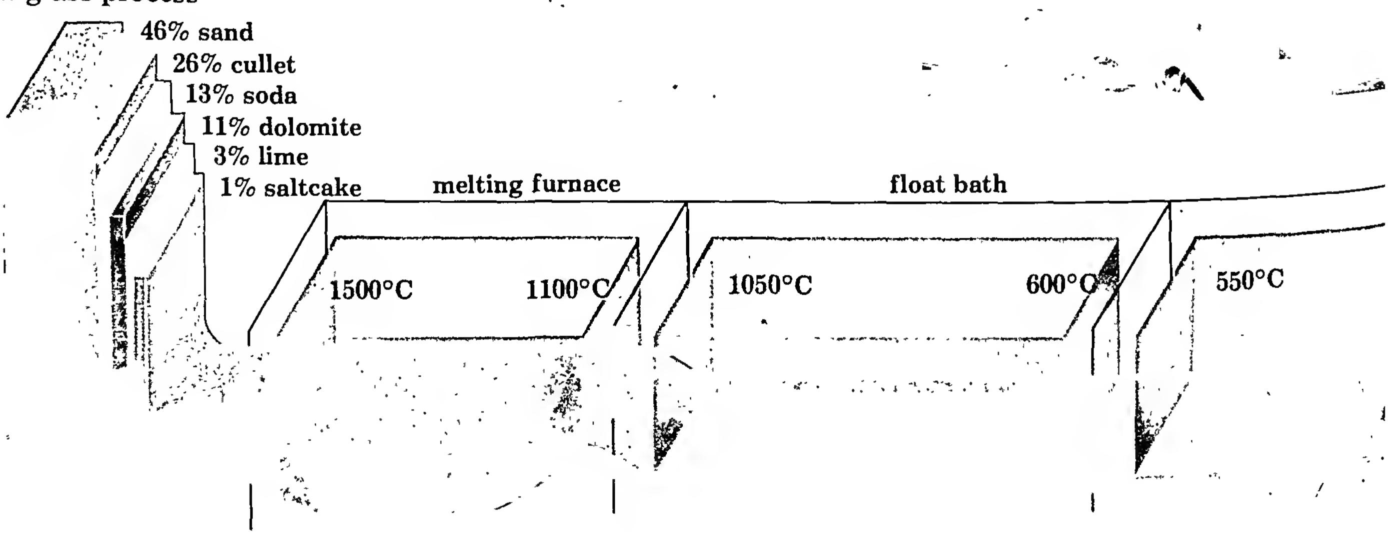
Glass can be made from sand alone, but the meltir point of sand is very high, about 3092 degrees F (17(degrees C). This kind of glass is not suitable for mo purposes, so about 10 percent of lime (calciu

Right: The end of the blowing iron is placed in the glass furnace and twirled so that it gathers a blob of molten glass.

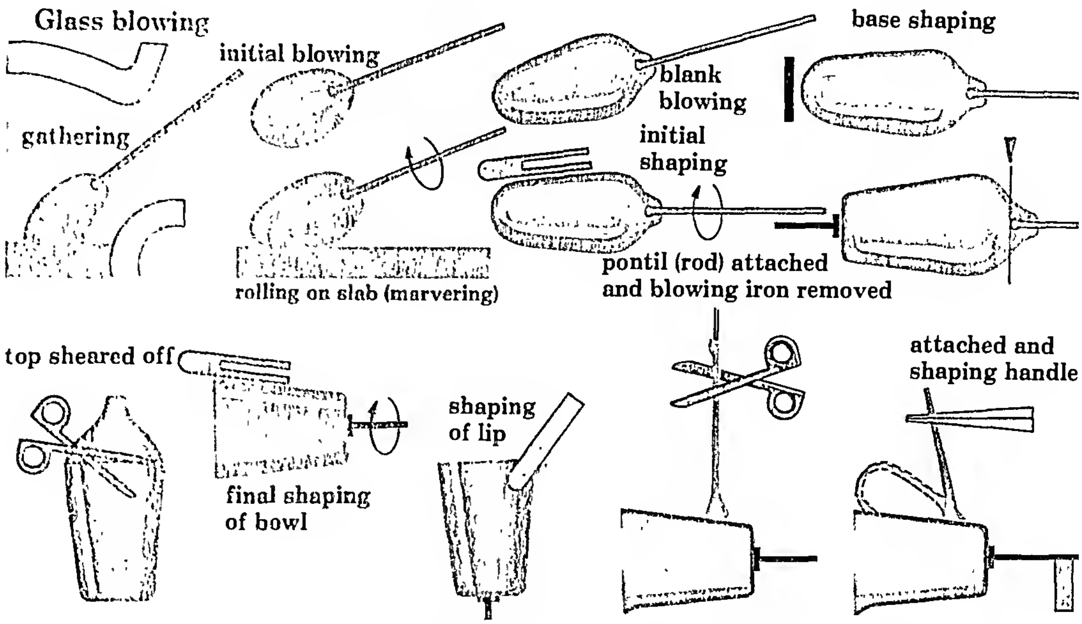
Far right: While the glass is still soft, it is blown to the required size and shape.

Below: The float process. On the left are the materials that are melted together to make glass. The molten glass is floated onto a bath of molten tin so that it forms a thin sheet. As it moves along, the glass cools and hardens.

Float glass process



Right: Glass blowing by hand is a craft that has been practiced for nearly 2000 years. Nowadays it is used mainly for making art objects. The pictures show how a simple glass jug is made by hand. This kind of work is carried out by skilled craftsmen.



carbonate) and 15 percent of soda (sodium carbonate) are added to the sand. This mixture melts at about 1560 degrees F (850 degrees C). Small quantities of other substances are often added, depending on the kind of glass that is needed.

The history of glass

No one knows where or when glass was first made. The first objects made entirely of glass appeared in ancient Egypt around 1500 BC. The Romans had cast window glass, but it was not very clear. This glass was cast in a flat sheet, and perhaps rolled while it was still hot to make it thinner.

Although a few churches had glass windows as early as the 7th century, large sheets of glass were not common until the 17th century.

In one early way of making glass, a sheet of the substance was cast in a mold, then rolled and polished. Another way was to use a long blowpipe to blow a blob of glass into a balloon. The balloon of glass was then spun rapidly on the end of the rod so that it flattened out into a disk. There are many small window frames still to be found with this crown glass in them. In the center of some of the panes is the thicker "bull's-eye" mark where the rod was attached to the glass.

Another way of making flat glass was to blow the globe, then swing it until it grew into a cylinder of glass about 5 feet (1.5 meters) long by 18 inches (45 centimeters) in diameter. The ends of the glass cylinder were cut off, it was then slit lengthwise and flattened in a kiln. This method of making sheet glass was used until the 20th century, when it was discovered how to draw up from the glass furnace a sheet of glass about as thick as hot taffy. The sheet is pulled up by asbestos rollers which grip the sheet as soon as it has cooled enough, a few feet above the furnace. The glass is slowly pulled up an ANNEALING tower which allows it to cool at a chosen rate. This is necessary to prevent flaws in the glass caused by the surface cooling too rapidly. The cooled sheet can then be cut to the required size.

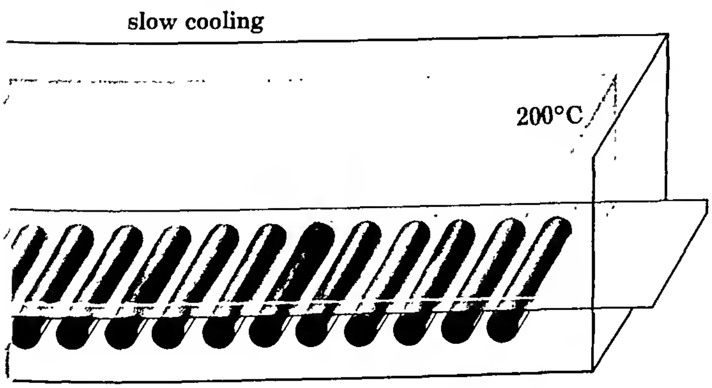


Plate glass

Plate glass is usually thicker than ordinary sheet glass. It is used in store windows and other places where a thicker, stronger sheet of glass is needed. It is made by passing molten glass between steel rollers. The long plate then goes through an annealing oven before being ground and polished on both sides as it passes along.

Float glass

In 1959, a great advance was made in the manufacture of sheet and plate glass. The float process introduced that year became the chief method of manufacture

worldwide. Previously, any flat plate glass had to be rolled and polished to remove distortion. But grinding and polishing wasted a lot of glass—as much as 20 percent—and was expensive.

In the float process, a continuous sheet of glass up to 11 feet (3.3 meters) wide moves out of the melting furnace and floats along the surface of a bath of molten tin. Because the surface of the tin is dead flat, the glass also becomes flat. The long sheet of glass cools down as it advances along the surface of the tin until it is hard enough to go through the annealing oven. The glass produced by this float process is of an even thickness all over and has a bright polished surface without the need for grinding and polishing.

Float glass can be made in any thickness from 1/10 to 1 inch (2.5 to 25 millimeters).

Safety glass

There are many uses for strong glass that will not shatter easily, such as in automobile windshields. These are made from annealed glass which goes through a further process of toughening. Its temperature is raised until the glass is just beginning to get soft. It is quickly lifted out of the furnace and cooled all over by jets of cold air. This makes the surface much stronger than normal.

Laminated glass for car windshields is made by sandwiching a layer of clear plastic between two sheets of strong float glass. The sandwich is gently heated in a vacuum to get rid of all the air from the material. It is then heated under pressure and the sandwich is bonded together. A number of layers may be used to increase the strength of laminated glass.

Glass containers

Bottles and other hollow objects are made by blowing. A piece of molten glass is placed in a mold. Air pressure is applied inside the bubble of glass, forcing the glass against the sides of the mold. There it hardens to the desired shape. Molds are usually made of cast iron, and they are in several pieces so that they can be opened to remove the bottle or other container.

This process is entirely automatic. Rates of production vary for different kinds of machine, but some are very fast. Light bulbs can be blown on a machine that produces over 2000 a minute.

Optical glass

The kind of glass used for spectacles, binoculars, microscopes and cameras is made very carefully. It must be completely free from streaks and bubbles. There are hundreds of different kinds of optical glass.

And, of course, glass can be beautiful to look at. For centuries, craftsmen have produced pieces of art glass. Today's artists are still fashioning beautiful objects from this strange and useful material.

See also: CONTACT LENS, FIBER GLASS, LENSES, STAINED GLASS

Right: Making glass bottles by high-speed machines. The streams of hot glass are cut into gobs. These are automatically placed in the molds and blown to the final shape.

Gold

Gold is the world's most important precious metal. It occurs naturally as the pure metal and can be refined easily. Because it is easy to work, it is used to make jewelry and has a number of industrial uses. It is also used as the basis of the world's currencies.

People have been mining gold for thousands of years. The main reason for this is that gold does not react easily with other substances. Unlike most other metals, it does not react with the oxygen in the air to form an OXIDE. As a result, gold occurs as the pure metal and can be REFINED simply by melting it to allow impurities to float to the surface.

Where to find gold

Gold occurs in small amounts in nearly all parts of the world. However, mining small deposits is too expensive and only in a few places is there enough gold present to make mining worthwhile. About 60 percent of the world's gold today is mined in South Africa. The U.S.A. and Russia each produce about 12 percent.

The chief sources of gold are veins of quartz that have penetrated older rocks. What are called alluvial deposits of gold are found where quartz veins have been eroded away and washed into rivers and seas. Small particles of gold are mixed with the silt and can be obtained by sifting them out.

Where alluvial deposits have been covered with other sediments and hardened under pressure and heat, the gold, sand and quartz pebbles form a concrete-like CONGLOMERATE. At the Rand gold field in South Africa, gold conglomerate is extracted from deposits thousands of feet underground.

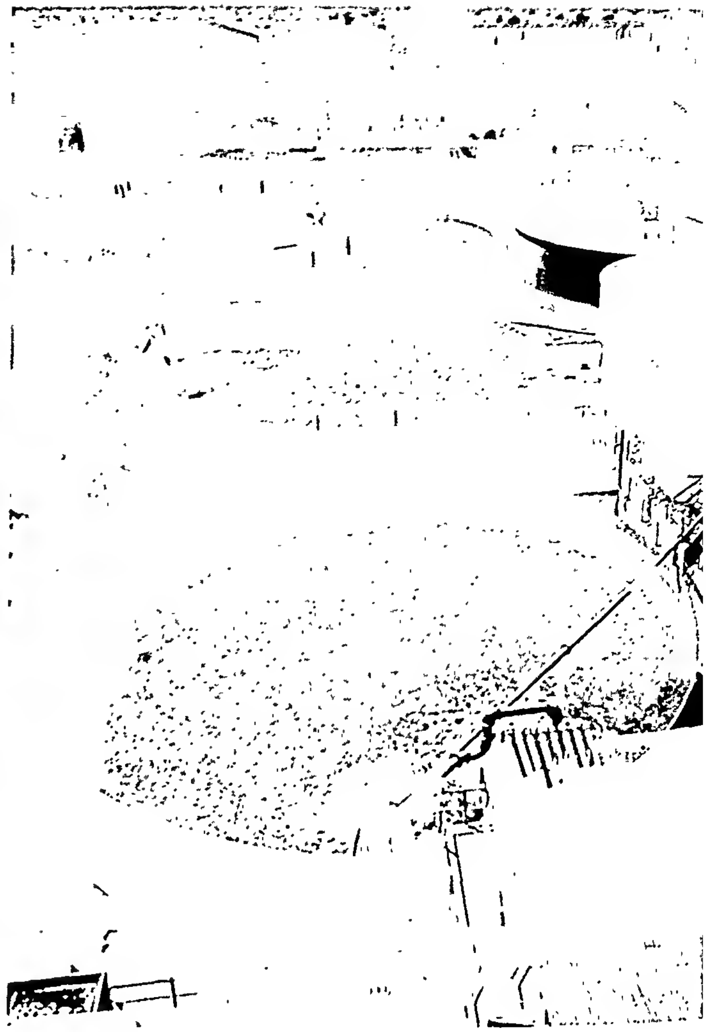
Gold ORE is first crushed in order to release the gold particles. The crushed ore is mixed with water to form a slime. Coarse particles can be separated from the rest of the ore by mechanical means—the heavier gold particles sink to the bottom as the mixture is shaken. Or, the gold can be removed by causing it to form an amalgam, or alloy, with mercury. The amalgam can then be distilled to recover the gold.

Very small particles of gold do not settle and are not easily extracted by the mercury amalgamation technique. Gold in this form has to be extracted chemically, using a process known as CYANIDATION. A dilute solution of sodium or potassium cyanide is added

Top right: Gold nuggets encased in quartz, mined from a quartz vein in Australia.

Bottom right: During the process of extracting gold by cyanidation, two Archimedean screws, known as classifiers, remove the coarse particles of rock from the slime.

Above: Molten gold is poured into molds where it solidifies into ingots.



Right: After cyanidation, the slime is passed to clarifying tanks. There the solids settle and the dissolved, gold-containing cyanide compound is passed to another tank.

to the slime and, in the presence of air, the gold forms a cyanide compound with the sodium or potassium. This compound dissolves in the water and can be separated in a clarifying tank. The solution is then held in a vacuum to remove all the dissolved air. Powdered zinc is added and this reacts with the cyanide compound to produce gold metal.

Refining

After gold has been separated from its ore, it still contains a number of impurities, such as base metals. Two processes are used to refine gold still further. In one process the gold is melted and covered with a layer of borax. Chlorine gas is then bubbled through the molten metal and most of the base metals form chlorides. Some of these are released as gases; others form a slag with the borax.

Gold can also be refined by electrolysis. In this process an electric current is passed through a solution of a gold compound. Gold metal is deposited on the negative electrode.

Uses of gold

Most of the world's gold is used as the basis of currency; about 60 percent of all gold mined ends up as INGOTS stored in bank vaults. However, because of its properties, gold has a number of other uses.

Pure gold is soft and is rarely used for jewelry. Instead, other metals, such as silver, copper, nickel and palladium are added to increase its hardness. The gold content is described in terms of carats. On this scale 24 carat is pure gold, 22 carat is at least 91.6 percent gold and 18 carat is at least 75 percent gold.

Because gold is soft, it can be worked easily. It can be rolled or beaten into thin sheets. Even thinner sheets can be obtained by electrolysis and VACUUM deposition (spraying gold vapor in a vacuum). Thin gold films are used in windows to reflect strong sunlight and in spacecraft heat shields.

Electronic devices

Gold does not CORRODE. As a result it is very useful for making reliable electronic devices. In some INTEGRATED CIRCUITS thin gold "wires" connect the various electronic parts. Gold is also used in medical implants because it does not react with the chemicals of the body. It has been used in dentistry for over a hundred years.

See also: DENTISTRY, ELECTROLYSIS

Grain Elevator

A bulk material, such as grain, can be moved from one place to another quickly by using an elevator. Various kinds of elevator are available and the type used depends on what the material is and how much is to be moved.

Bulk materials often have to be moved from one place to another in as short a time as possible. To do this it is necessary to use a machine that automatically picks up the material at one end and discharges it at the other.

Some materials, such as limestone, consist of fairly large lumps and there is only a limited number of ways in which these can be moved. Grain, on the other hand, consists of very small particles and in some ways behaves like a liquid; that is, it can be made to flow smoothly and can be sucked up through a tube.

Bucket elevators

The most common type of material-moving elevator uses buckets to pick up and deliver. The buckets are fixed to a chain or belt and filled by hauling them through the material. Many materials can be moved in this way, including both limestone and grain. Depending on the material that is being moved, it is discharged from the buckets either by being hurled out (centrifugal discharge) or by being tipped out (positive discharge).

Bucket elevators vary in size. The smallest ones lift about 2 tons an hour over a height of about 10 feet (3 meters). The largest types can haul grain to a height of 300 feet (91 meters) at the rate of 2000 tons an hour.

Conveyor belt elevators

Conveyor belt elevators are small simple versions of this type of elevator. Instead of buckets there are a series of BAFFLES on the belt that prevent the material from slipping back. Unlike bucket elevators, however, conveyor belt elevators cannot lift materials vertically. They can move materials up only a fairly gradual incline.

Pneumatic elevator

A pneumatic elevator (shown next page) uses air pressure to push grain along a flexible tube. A moving stream of air is created in the tube by a fan or rotary blower. This type of elevator is used in docks for unloading grain from the holds of ships. The flexible tube can reach down into the hold regardless of the state of the tide or how low the ship is lying in the water.

A large elevator on a fixed jib (a projecting arm) can unload a ship at the rate of 2000 tons an hour. The grain is discharged into large silos. Smaller pneumatic elevators mounted on mobile trailers can unload the silos into grain transporters at the rate of about 80 tons an hour.

Chains and screws

Because grain flows like a liquid, even though it is in fact a solid, it can be pushed along a tube. Each grain pushes against its neighbor and the whole lot moves along en masse (a French term that means "in bulk"). The so-called en masse principle is used by two kinds of elevator—the chain-type elevator and the Archimedean screw elevator.

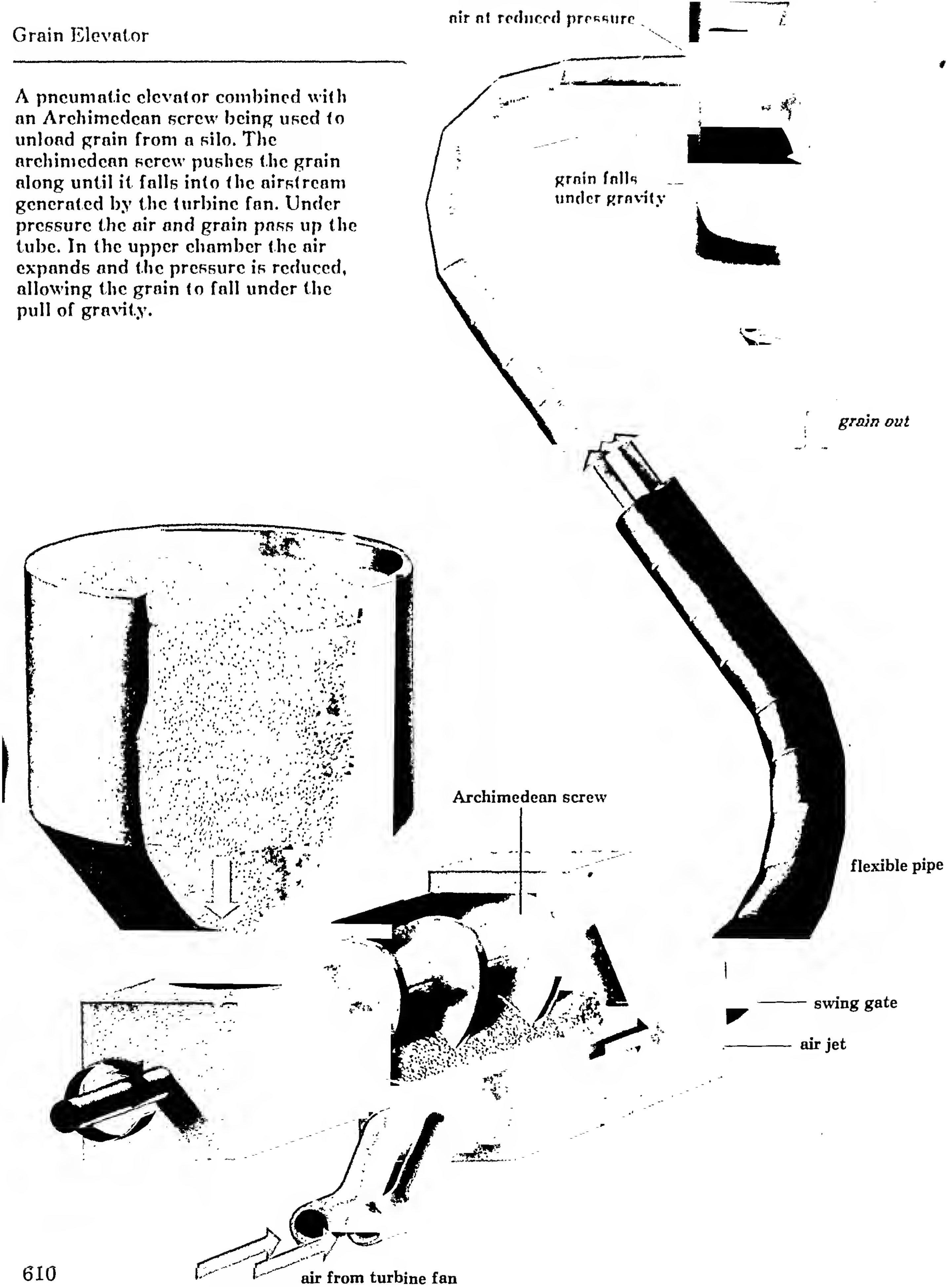
A chain-type elevator consists of a long, rigid tube along which a chain runs. The links of the chain are extended outwards to form "paddles." Once the tube is filled, the paddles push the grain along. Grain can be lifted vertically or moved horizontally using this type of elevator.

An archimedian screw elevator consists of a rigid tube about 30 feet (9 meters) long. Inside the tube a long rod acts as the central axis of a spiral blade—like the spiral blade in a household grinder. As the rod turns, the blade pushes the grain along. An archimedean screw elevator is generally used at a maximum incline of about 80 degrees to the horizontal. However, a modified version can be used to move grain vertically. Archimedean screws can move 20 to 30 tons an hour and are used in agricultural machinery.

See also: ELEVATOR

Below: The hose of a pneumatic elevator unloading grain from a ship's hold.

A pneumatic elevator combined with an Archimedean screw being used to unload grain from a silo. The archimedean screw pushes the grain along until it falls into the airstream generated by the turbine fan. Under pressure the air and grain pass up the tube. In the upper chamber the air expands and the pressure is reduced, allowing the grain to fall under the pull of gravity.



Gravity

There is a force that keeps the moon from crashing down into the earth and keeps the earth moving constantly around the sun. That force is known as gravity. We would not have satellites or rockets in space if the law of gravity had never been discovered.

Galileo (1564–1642), the famous Italian scientist, threw stones of different sizes off a tower to test whether the big ones would fall faster than the smaller ones. He discovered that all the stones hit the ground at the same time.

He also attached a piece of string to stones and swung them like a pendulum. In the test, he found that the stones always took the same time to make one swing, if the string were kept the same length. It did not matter about the size of the stones.

In a third test, Galileo rolled balls down a slanted piece of smooth wood, which he marked off in equal measurements of seconds. He learned that, no matter what size the ball, it rolled faster toward the end than at the beginning.

Galileo made these experiments and many more in the 16th century, when he was a professor at the University of Pisa. He got into trouble with the authorities because his tests went against what people then believed to be fact. But he was proved right later when 17th and 18th century scientists formulated (stated in a clear way) the law of gravity.

The falling apple

Isaac Newton (1642–1727), the English scientist, is the hero of one of the most famous stories about making a scientific discovery. It is said that he got the idea about the law of gravity when he saw an apple fall as he sat beneath the tree. However, Newton himself wrote that he got his first clue from the moon. He tried to understand why the moon stays in the sky and does not fall down to earth.

He reasoned that if someone could throw a stone far enough and fast enough, it would take a curving path that matched the curve of the earth. In this way, it would never hit the ground. Instead, it would go on

Below: An artificial satellite in orbit around the earth. The force of gravity keeps it from flying off into space. The same kind of gravitational force keeps the planets moving around the sun without crashing down.

circling the earth in orbit (constant movement in one path). Newton said that the moon moves with just enough speed to overcome the earth's gravity, like the stone would, and so stays in orbit.

In his work on gravitation and gravity, Newton proved two laws that had been formulated by Johannes Kepler (1571–1630), a German astronomer. The first of these laws stated that planets travel around the sun in elliptical (oval) orbits. The second law says that the line which joins the planet to the sun's system makes a sweep of equal distances in equal times. This means that a planet near the sun must move quite fast, and a planet farther from the sun must move more slowly.

Newton also believed that the force of gravity is what gives weight to a body pulled toward the earth. John Henry Poynting (1852–1914) is the scientist who proved this. He hung two small balls of lead alloy from each side of a specially built balance and placed a large sphere on a balance below one of them. The gravitational attraction between the two balls tilted the balance.

Gravitation and gravity

Gravitation is a force of attraction between any two bodies in the universe, from the heavenly planets to the smallest particle of matter. The sun's gravitational pull holds the planets, including the earth, in orbit. The planets are satellites of the sun.

Gravity is also the force that draws bodies toward the earth. The moon is the only natural satellite of our planet, but there are many artificial satellites in space.

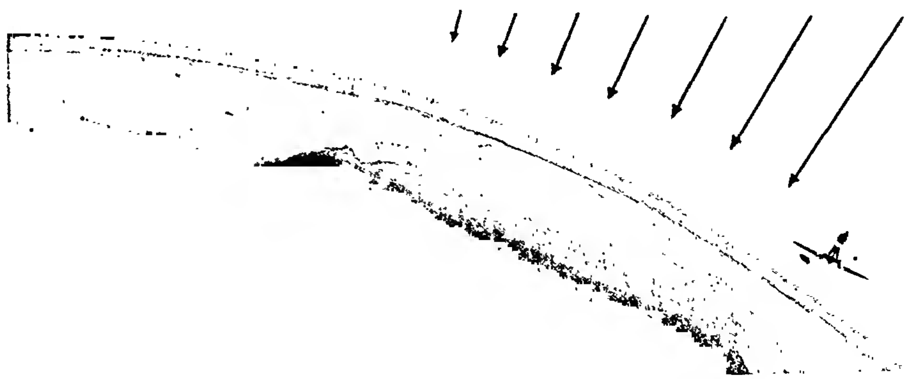
The force of gravity pulls these satellites toward earth, so they do not go flying off into space. It is easier to understand this force if you tie an object to a piece of string and whirl it around. The tension in the string is like the earth's gravity. It will keep the object constantly circling (unless, of course, the string breaks).

Gravity gives a falling body an even speed. That is, the speed at which it falls increases the same amount for each second it is falling. Galileo's test with the balls rolling down a plane demonstrated this fact.

Above: An astronaut during tests to see how his heart will hold up in space travel. The graph show irregular heartbeats.

Rockets and satellites are launched according to law of gravity. They are set high enough and f enough to overcome the earth's gravity and remair orbit.

See also: ORBIT, PHYSICS, ROCKETS



Right: If there were no gravity, a spacecraft would travel in a straight line. But the gravity of a planet, such as the earth, moon or sun, will pull it into a curved orbit.

Grenade

A grenade is a small bomb that may be thrown by hand or fired from a rifle. Grenades can contain high explosive that throws out metal fragments. They may also be made to produce smoke or tear gas, or to fire signal and light flares.

Early grenades in the 14th and 15th centuries were made of glass, clay or earthenware filled with black powder. They were intended to produce fire rather than a blast. These grenades were not very effective.

The early grenades were followed by others with metal bodies. But soldiers using these weapons were almost in as much danger from their own grenades as the enemy were because of the unreliable fuses.

It was not until the early 1900s that more reliable fuses were produced, though the problem of fixing the firing time remained. (Firing time is the time between throwing the grenade and its explosion.) If the firing time was too long, the enemy could pick up the grenade and throw it back before it went off. If the firing time was too short, the grenade could kill the thrower.

Modern grenades

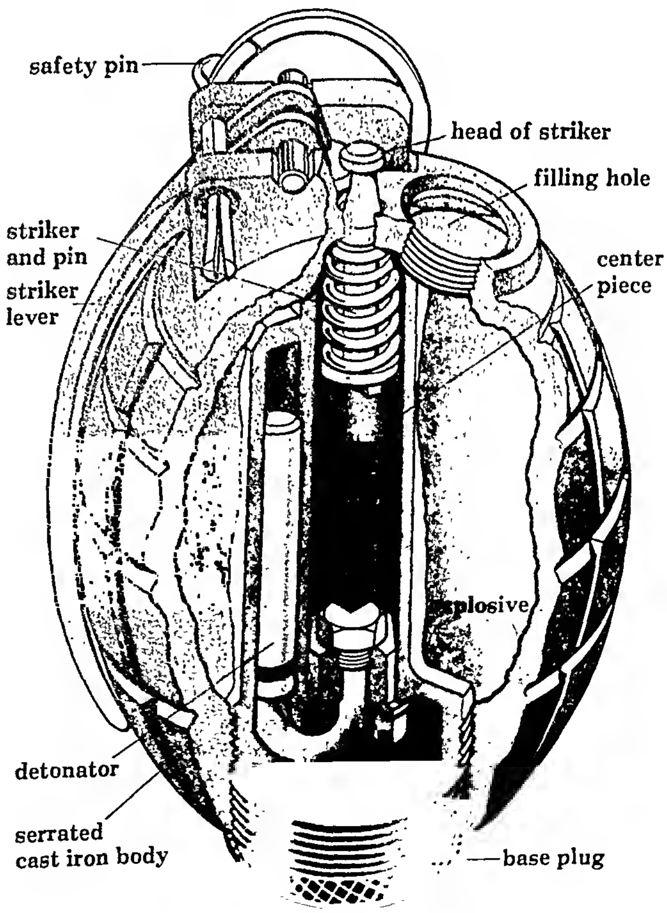
Modern anti-personnel grenades have three main parts: 1. A fuse and detonator that are set off by a spring-loaded striker hitting a percussion cap (with about a 5-second delay before the explosion); 2. A highly explosive filling; and 3. A case of engraved steel or wire that shatters when the explosion takes place.

Grenades are used by troops and police to help control riots. These anti-riot grenades are often filled with CS gas, an irritant that makes its victim feel as though he has been attacked with pepper. CS stands for two Americans, Carson and Staughton, who discovered the properties of the gas in 1928.

See also: AMMUNITION, BOMBS, GUNS

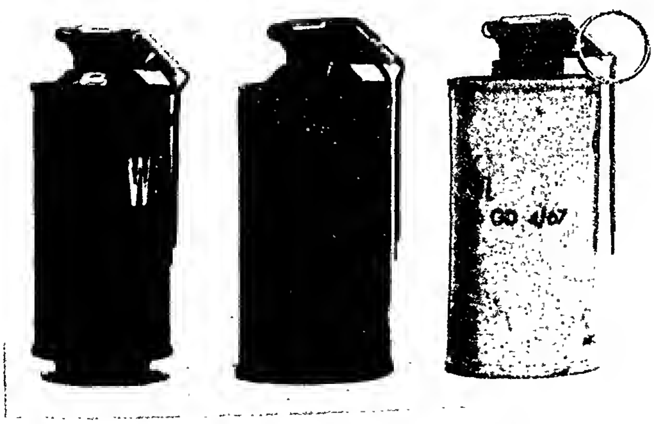
Did you know?

Grenades got their name from the Spanish word *granada*, meaning pomegranate. In the early days of their use, grenades were round and filled with large grains of black powder. People thought that they looked rather like pomegranates with their large seeds.



Right: A Mills hand grenade. The firing pin is held up by the striking lever. When the safety pin is pulled out, the lever flies up, the spring is released and the firing pin hits the detonator cap. The detonator fuse sets off the explosion after a few seconds.

Below: Three types of grenade. On the left is a smoke grenade. In the center is a riot control grenade which gives out an irritant gas. On the right is a signal grenade that can produce red, green or yellow smoke.



Guns

A gun can be anything from a great cannon to a small pocket pistol. The main kinds of small arms are pistols, rifles, shotguns and machine guns. They all work on the same principle. A cartridge is placed in the breech. When the trigger is pressed, a firing pin or hammer hits the base of the cartridge, setting off a percussion cap. This fires the gunpowder or other explosive in the cartridge. The gases drive a bullet or lead shot up the barrel.

Guns seem to have appeared in China about AD 1250. These early guns fired arrows instead of balls or bullets. Larger guns, or cannon, were known in Europe by 1326, and they may have been used even earlier. These were fired by pouring gunpowder into the barrel and placing a metal ball on top of it. A burning taper was applied to a touch hole in the breech that was filled with powder. This fired the cannon. These early guns were so crude they were just as likely to kill the firer as the enemy.

Firing mechanisms did not appear until about 1400. They led to the guns that we know today.

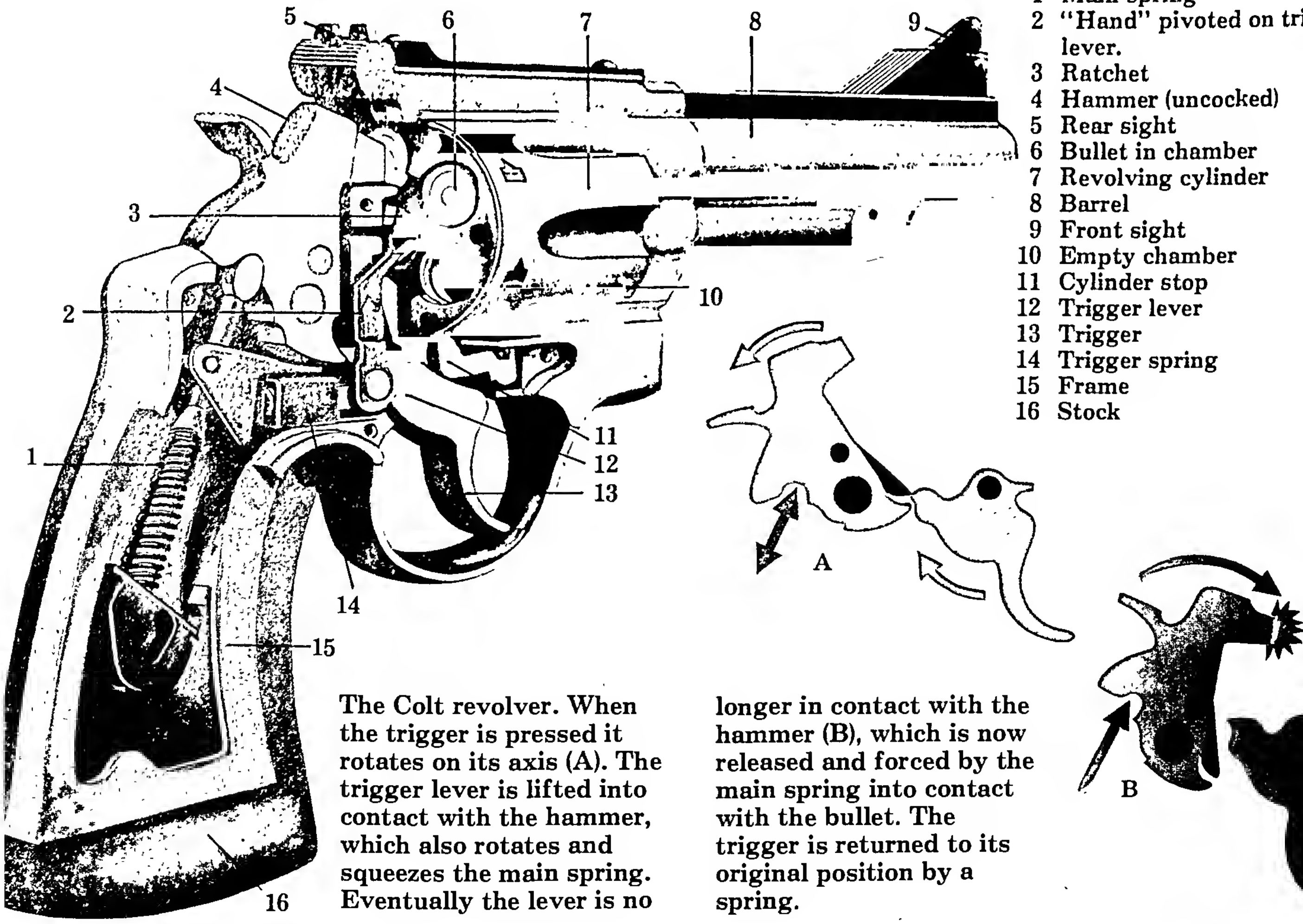
In the 1400s came the matchlock. This had a trigger-operated device for moving a slow-burning cord, or match, to the touch hole. Then, in the 1500s, came the wheellock which worked on the same principle as the cigarette lighter. Pulling the trigger turned a wheel and brought a piece of iron pyrites down to strike a spark.

The flintlock succeeded the wheellock in the 17th century. Its firing mechanism produced an "instant" spark to ignite the powder. Nearly all firearms until the early 1800s were flintlocks. The double-barreled sporting gun appeared about the middle of the 18th century as a flintlock.

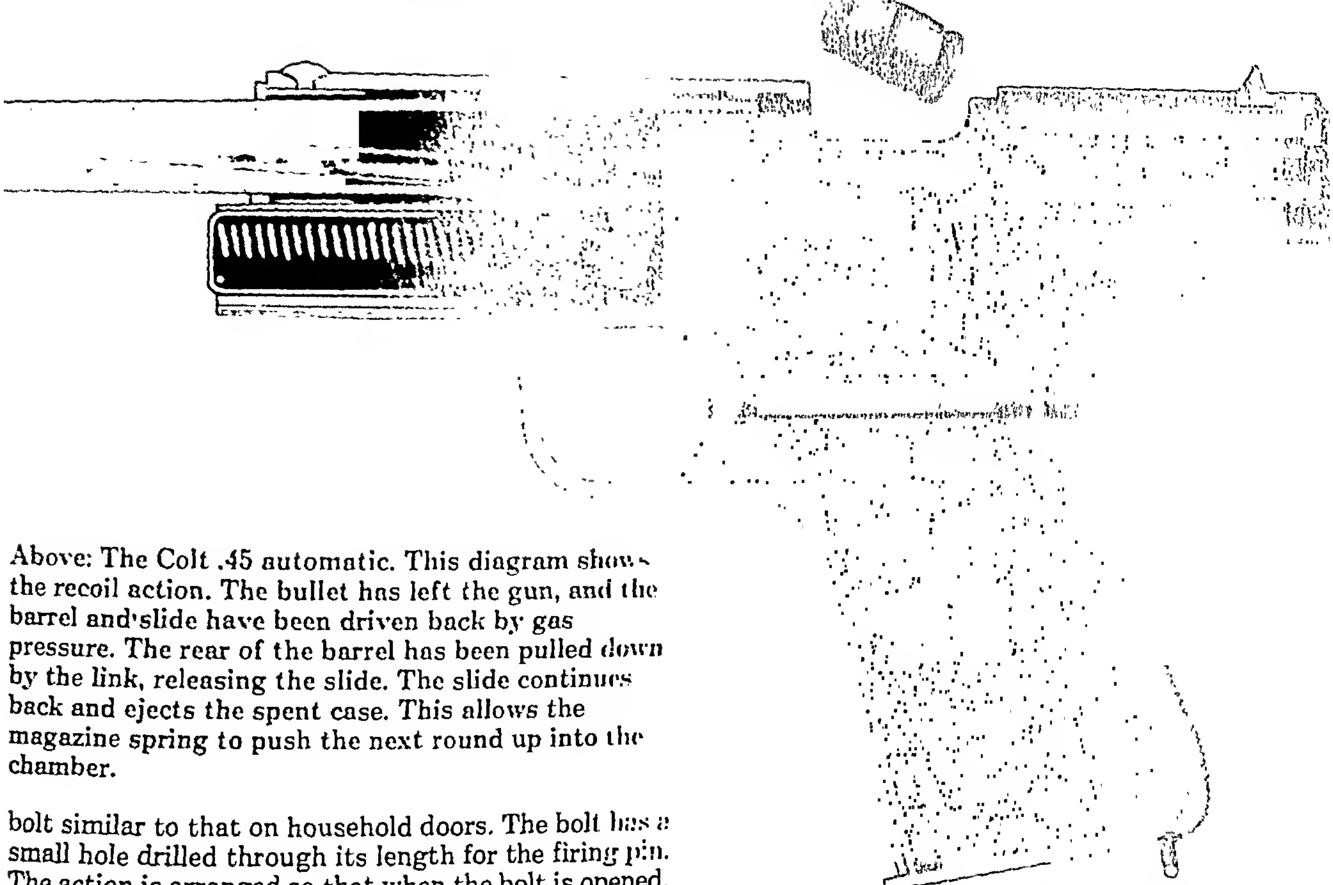
Rifled guns

Most guns (except shotguns, which fire lead shot) have rifled barrels. Rifle barrels have spiral grooves on the inside. These grooves make the bullet spin and travel in a straight line.

Bolt action rifles have changed little in the last seventy years. In these rifles, the breach is closed by a



The Colt revolver. When the trigger is pressed it rotates on its axis (A). The trigger lever is lifted into contact with the hammer, which also rotates and squeezes the main spring. Eventually the lever is no longer in contact with the hammer (B), which is now released and forced by the main spring into contact with the bullet. The trigger is returned to its original position by a spring.



Above: The Colt .45 automatic. This diagram shows the recoil action. The bullet has left the gun, and the barrel and slide have been driven back by gas pressure. The rear of the barrel has been pulled down by the link, releasing the slide. The slide continues back and ejects the spent case. This allows the magazine spring to push the next round up into the chamber.

bolt similar to that on household doors. The bolt has a small hole drilled through its length for the firing pin. The action is arranged so that when the bolt is opened, the firing pin is withdrawn and cocked ready for the next shot.

The first bolt action rifles were all single-shot. Each cartridge had to be put into the bolt-way and the empty case pulled out and thrown away. But it was not long before repeating rifles were made. In these types of gun a MAGAZINE holding several cartridges fitted below the bolt and the cartridges were pressed upward by a spring. As the bolt is pushed forward, it strips a cartridge off the top of the magazine and pushes it into the breech. An extractor pulls out the empty case. Speed of firing depends on how fast the shooter can operate the bolt. Some bolt action rifles are still in use. A rifle of this type can fire a bullet to a range of well over 2000 yards (1800 meters). It can hit a target 2 feet (60 centimeters) square at half a mile (800 meters).

Military rifles are no longer hand-operated. They all use some kind of self-loading system which only requires the soldier to aim and pull the trigger.

Shotguns

A shotgun is a smooth-bore (not rifled) weapon that fires small shot or pellets. Its main use is for shooting birds or small ground game. The shotgun shoots out a large number of pellets which spread out as they leave the barrel. The aim therefore need not be as accurate as when firing a rifle.

The range of shotguns is usually quite short. They are not very efficient beyond about 50 yards (45 meters). Most shotguns fire about 1 ounce (28 grams) of lead pellets. The pellets are graded in size, but for most game shooting there are about 280 pellets to the ounce (10 per gram).

Shotgun cartridges are made of cardboard or plastic, with a thin brass base. They produce low pressure compared to rifles. This means that shotgun barrels can be made quite light. A good double-barreled shotgun weighs less than 6 pounds (2.7 kilograms).

The revolver

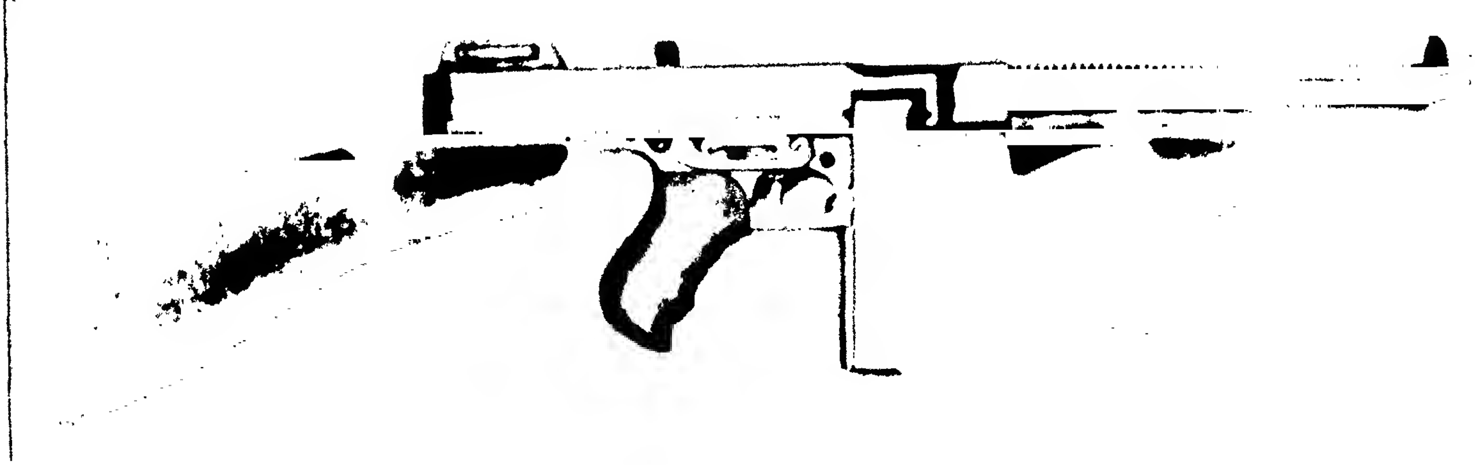
One man can be said to be the father of the modern revolver—Samuel Colt. The revolver design he made in 1836 laid the pattern for the future.

The revolver is a firearm in which a cylinder with a series of chambers for the cartridges revolves. In this way, each chamber containing a cartridge is presented to the firing mechanism in turn.

The present day revolver closely resembles the original Colt, but there have been improvements. There are now two basic kinds of revolver: the single action and the double action. Most of the early revolvers were single action, but this kind is now used only as a target weapon.

In the single action revolver, the hammer is pulled back by the shooter's thumb. This cocks the hammer and rotates the cylinder round to the next chamber. Then all that is needed is a light pull on the trigger.

In the double action revolver, the trigger not only fires the shot, it also cocks the hammer and rotates the



Above: The 1921-model Thompson sub-machine gun. It had a 20-round magazine of .45 cartridges. The magazine could be emptied in less than two seconds.

cylinder. To perform these actions, the trigger has to travel quite a long way and its pull is rather heavy. This means that the weapon is difficult to aim accurately. The double action system tends to be used for close-range shooting only.

Nearly all modern revolvers have six chambers. There are two different ways of loading. Either the cylinder drops to one side, or the barrel and cylinder unlock and tilt forward, exposing the chambers for the cartridges. With each type, an ejector expels the empty cases in one movement and new cartridges have simply to be dropped in and the gun closed.

The main advantage of the revolver is the fact that it is the most reliable repeating weapon ever made. The way it works is so simple that it is almost impossible to jam.

The automatic pistol

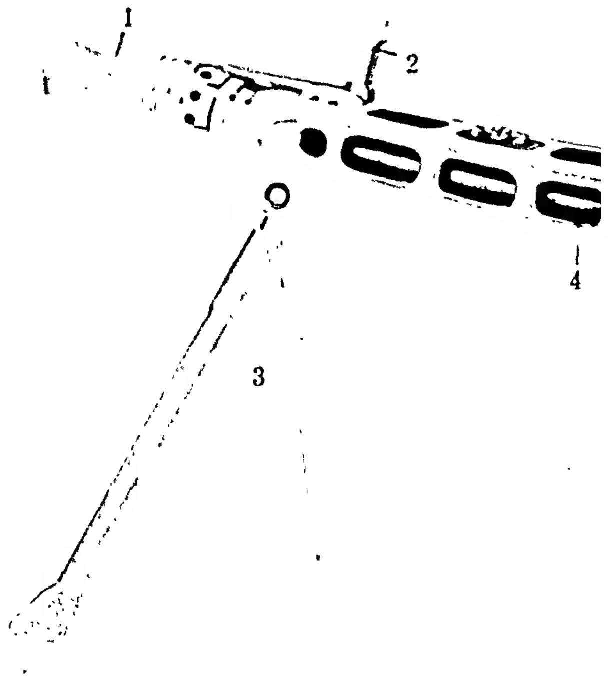
The first well-known automatic pistol was the Luger. The designer of this pistol, Hugo Borchardt, was an American, but he had to take his pistol to Europe to find a manufacturer. This pistol was the first to have a preloaded magazine which could be fitted into the han grip. The Luger was produced in Germany in 1898.

In 1903 the Colt Hammerless .32 automatic pistol designed by John Browning, appeared. This was copie by a large number of manufacturers in Germany Belgium and Spain. Then, in 1911, came the famou Colt .45. It became the standard side-arm of the U.S forces and is still in service.

Automatic pistol magazines contain six to 16 rounds depending on the size and caliber. To prepare for firing the slide is pulled fully back. This places a cartridge ir the chamber. When the slide is moved forward again the barrel is locked onto the slide. When the gun is fired, a complicated mechanism ejects the empty cartridge case and feeds in a new round.

Machine guns

The first really successful rapid fire gun was that of Dr. Gatling, first demonstrated in 1862. It had a circle of barrels which rotated and fired in turn. This gun



Right: A German MG42 machine gun. The bolt is driven forward by the recoil spring when the trigger is pressed. The bolthead drives a cartridge into the barrel chamber and is locked in position by the locking piece. A further small movement forward of the bolt (red arrow) fires the round. The barrel and bolt recoil, and the locking piece releases the bolthead. The cycle is then repeated.

1 Flash hider
2 Front sight
3 Bipod
4 Barrel
5 Feed cover (open position)
6 Feed arm
7 Feed mechanism
8 Rear sight
9 Locking piece
10 Cartridge belt
11 Bolt
12 Trigger
13 Pistol grip
14 Plastic stock
15 Recoil spring
16 Bolt stud
17 Sear
18 Bolt head
19 Bolt

remained in service in the U.S. Army until 1911. It was worked by the operator turning a crank (handle).

During World War I, nearly all armies used the Maxim machine gun. It was invented by the self-taught American electrical engineer, Hiram Stevens Maxim.

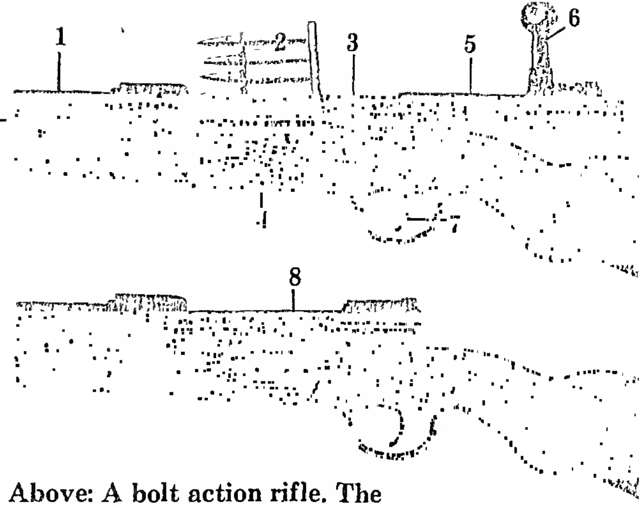
The Maxim was different from all the other guns in that the power to carry out all its operations—feeding, locking, firing, extraction, ejection—came from the energy of the propellant. The gun was operated by the recoil of the barrel and breech block caused by the gas pressure. This principle is still used in most modern machine guns.

Lighter machine guns

A change that began in World War II was the replacing of the single-shot rifle by self-loading rifles and sub-machine guns. These weapons are light machine guns that are hand-held when fired. One of the most important guns is the M16 rifle used by the U.S. forces.

The machine gun has been one of the most important weapons in history. The tank was invented as a means of moving across the battlefield in the face of machine gun fire.

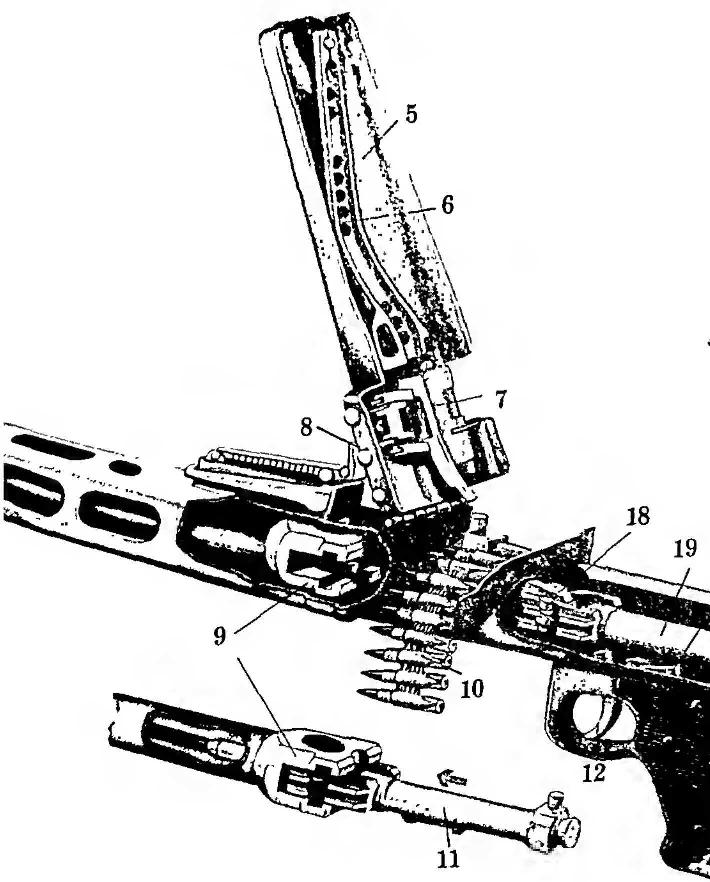
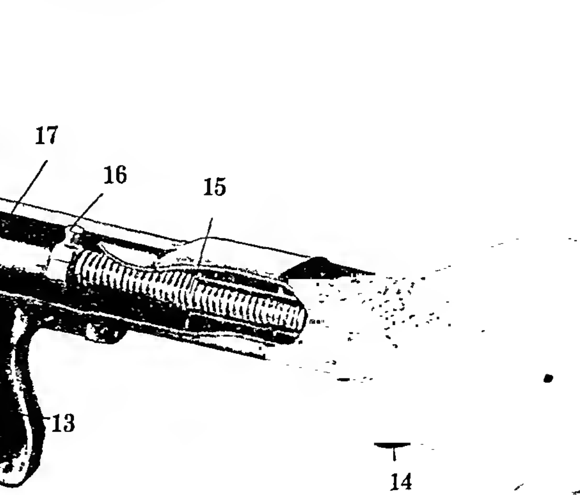
See also: AMMUNITION, BALLISTICS



Above: A bolt action rifle. The rifle is unlocked by turning the bolt handle and pulling back the bolt mechanism. The cartridges are dropped into the magazine. When the bolt is pushed home it chambers the top cartridge and cocks the gun. On squeezing the trigger, the mainspring is released, forcing the firing pin against the cartridge. Pulling back the bolt ejects the cartridge.

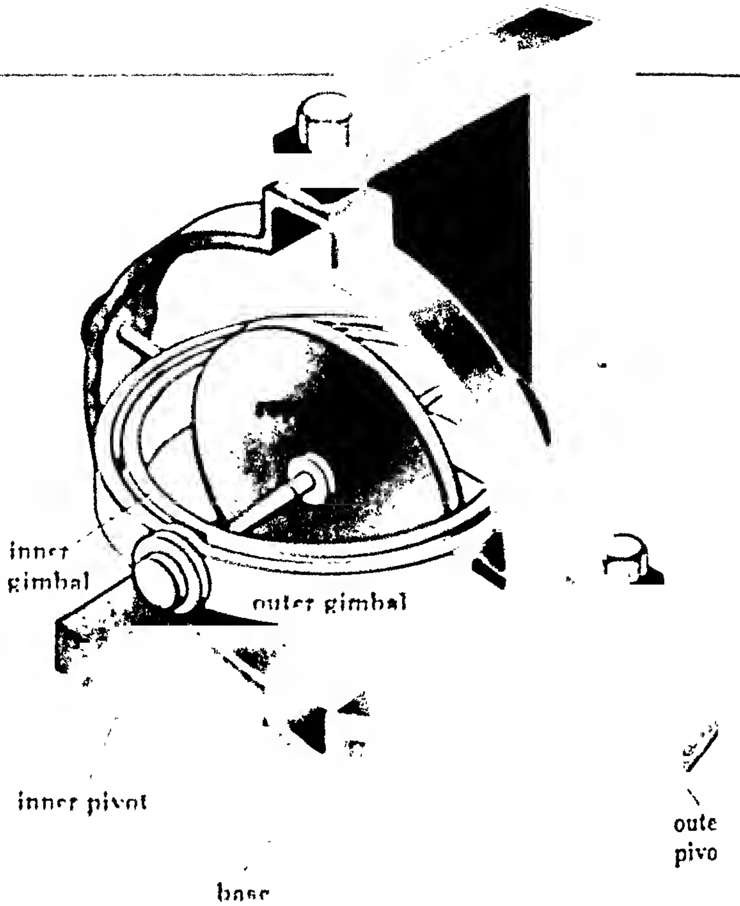
1 Barrel
2 Cartridges
3 Firing pin
4 Magazine
5 Bolt mechanis
6 Bolt
7 Trigger
8 Mainspring

Above: A modern general-purpose machine gun. It is gas operated.

Gyroscope

The gyroscope is a fascinating device with a spinning wheel that can be made to perform amazing tricks. It is made use of in a variety of instruments. These include the gyro-compass, used for navigation in practically all planes and ships.



Above: The construction of a simple gyroscope. The rotor is mounted to gimbals within a frame in such a way that it is not affected when the frame moves.

Toy gyroscopes

The gyroscopes sold as toys usually consist of a rotor and axle that pivot in a single ring. The rotor is set spinning by wrapping a piece of string around the axle and pulling. Projecting beyond the axle pivots are small rods with spherical ends. The gyroscope rests on these.

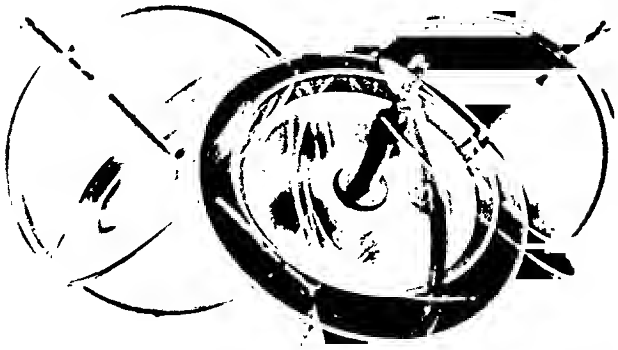
Once set spinning, even this simple gyroscope can perform astonishing balancing tricks, appearing to defy the laws of gravity. It can balance on the edge of a knife, on a "tightrope" of string, and on the top of a pencil.

When balancing on the tip of a pencil, the gyroscope as a whole gradually starts to move around in a circle. This effect is called PRECESSION. It is caused by the gyroscope's weight, acting downward. Precession also occurs with a spinning top—even with the earth spinning in space.

How it works

It is the rapidly spinning wheel, or motor, that gives the gyroscope its remarkable properties. Usually the rotor axle is mounted within a system of pivoted rings, or gimbals (see diagram, right).

Once the rotor is set spinning inside the gimbals, it becomes very stable. It will always remain pointing in the same direction in space even though the frame is moved. If the gyroscope axle is pointed first at the sun, for example, it will gradually follow the sun across the sky. This is because the sun remains in the same position in space, while the earth turns on its axis. This directional property of the gyroscope makes it indispensable for navigation.



Below left: A toy gyroscope balancing on the tip of a pencil processes (moves slowly round), as shown in this multi-exposure photograph.

The gyrocompass

A gyroscope in gimbals forms the basis of the gyrocompass, which planes and ships use to find directions. The gyroscope rotor is first set spinning, with the gyrocompass indicating the correct direction. The compass will continue to point accurately for as long as the rotor spins. It is spun by electricity.

The directional properties of the gyroscope are also made use of in the inertial guidance navigation systems used in submarines, missiles and spacecraft. The gyroscopes sense every change in direction along the three axes and feed this information to a guidance computer.

See also: COMPASS, NAVIGATION

H-Bomb

The H-bomb, or hydrogen bomb, taps the source of power that keeps the sun shining. It is the most terrifying weapon ever produced by humans, with the strength of millions of tons of ordinary high-explosives.

The sun and the other stars are made up mainly of hydrogen. In their interior, where the temperature reaches millions of degrees, the hydrogen is converted into a heavier element, helium. While that is happening, great amounts of energy are released, as heat, light and other RADIATION.

Heat makes it work

This process is called nuclear fusion. The nuclei (centers) of hydrogen atoms combine, or fuse, together to form the nuclei of helium atoms. Nuclear fusion is termed a thermonuclear reaction because heat is required to make it work (thermo means heat).

In the H-bomb, scientists start this process, using two heavy forms, or isotopes, of hydrogen called deuterium and tritium. But these will combine to form helium only at temperatures of several hundred million degrees. The only way of producing temperatures that high is by means of an atomic-bomb explosion. So the H-bomb uses an A-bomb as a trigger.

The United States exploded the first H-bomb in 1952 at Bikini atoll in the Pacific Ocean. The Russians tested their first H-bomb two years later.

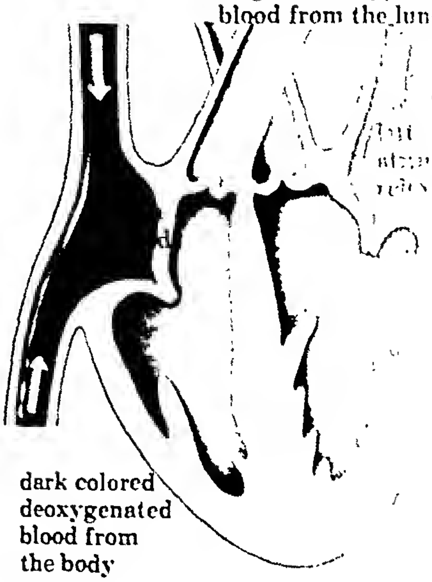
Megaton blasts

The H-bomb is hundreds of times more powerful than the A-bomb. It has the same explosive power as millions of tons (megatons) of the ordinary high explosive TNT (trinitrotoluene). It produces a gigantic fireball that rises high into the atmosphere, and releases its energy as heat, light, blast, and penetrating radiation. Dropped in a built-up area, a 10-megaton bomb would cause total damage over a radius (circular space) of up to 10 miles (16 kilometers).

Several different kinds of H-bombs can be made. For "fuel" some H-bombs use a compound called lithium deuteride, which is a combination of the metal lithium and deuterium. Other H-bombs are surrounded by a layer of uranium. When the explosion takes place, this uranium acts like another A-bomb to produce even more power. It also creates a lot more fallout. This is deadly radioactive material that eventually falls to the ground, often hundreds of miles away from the site of the explosion.

See also: A-BOMB, BOMBS, HYDROGEN

Right: A billowing mushroom cloud rises high into the atmosphere after the explosion of an H-bomb.



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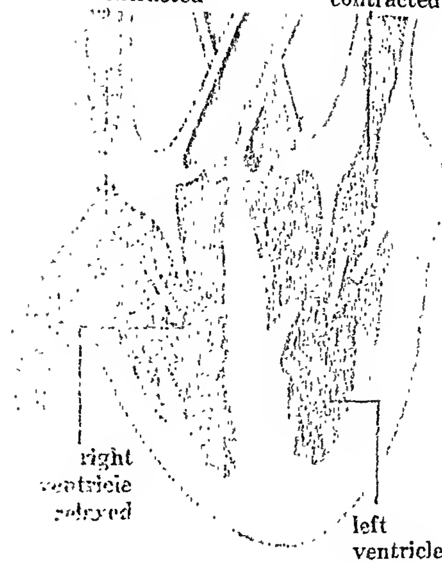


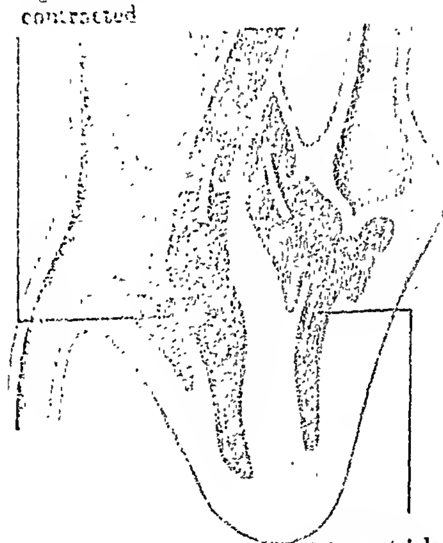
2

1 The right atrium receives dark blood, filled with waste carbon dioxide, from the body. The left atrium gets red blood, freshened with oxygen, from the lungs.

2 The right atrium contracts and pushes blood into the right ventricle. The left atrium contracts and pushes blood into the left ventricle.

3 The right ventricle contracts and pumps dark blood into the lungs. The left ventricle contracts and pumps red blood out into the whole body. Throughout this pumping process, the valves open and shut as necessary. Both sides work at exactly the same moment.

4 The ventricles relax. They are once again ready to receive blood and begin work as described in step 2.



3

4

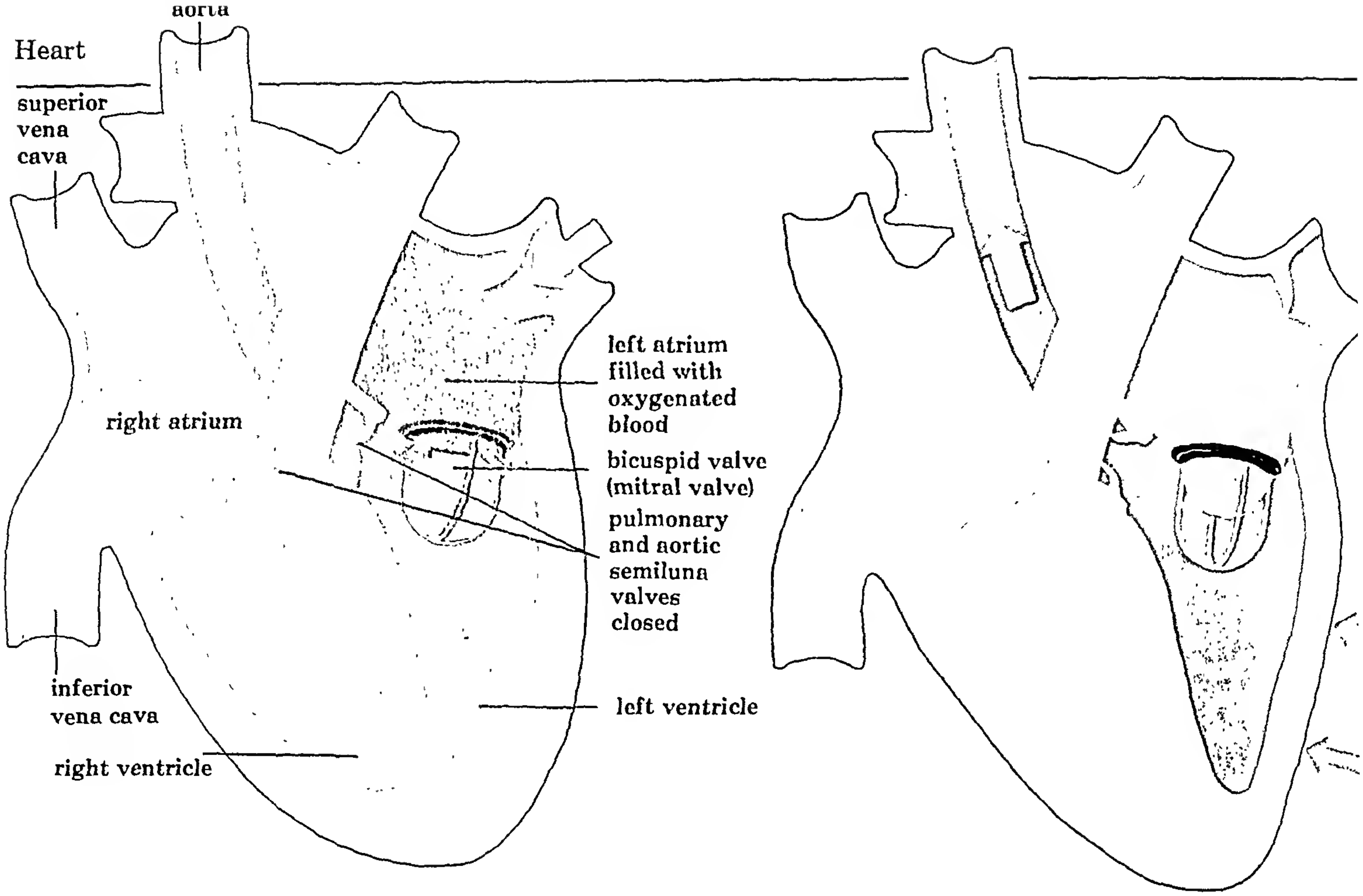
Did you know?

The heart works very hard. It pushes the blood around the body in a complete circuit more than 1000 times every day. This means that if you live to be 70, your heart would have pumped 44 million gallons (200 million liters) of blood in your lifetime.

The heart at work

There are two sides to the heart, which are divided by a wall of muscle called the SEPTUM. Each side has two chambers in it. Each upper chamber is called an atrium (plural, atria) and the lower ones are ventricles. The left side of the heart sends blood throughout the body and the right side pumps blood only through the lungs. Blood goes out through arteries and returns through veins. It is kept from backing up into the chambers by a series of valves that open and shut automatically.

From the left side, the blood first goes into the aorta, which is a very large artery. It is carried to where it is needed by the many other arteries of the body. As the blood moves around, it gives up its oxygen to the body and collects the waste carbon dioxide. Through veins



called the VENA CAVA, blood returns to the heart's right side to get rid of the waste material.

The right side pumps blood into the lungs through the pulmonary artery. The lungs replace the lost oxygen in the blood, and the refreshed (oxygenated) blood is returned to the left side through the pulmonary vein.

Both sides of the heart go through all their motions at exactly the same time, so only one heartbeat is felt as the pulse.

When the heart does not work

People describe heart trouble by calling it a heart attack. The medical term for this is CORONARY THROMBOSIS (heart blood clot). This happens when a blood clot blocks one of the arteries leading to the heart. A heart attack may bring instant death. Sometimes it causes bad damage to the heart muscle and makes a person an invalid. Or it can be so mild that a person recovers almost completely.

Not long ago, no one could operate on the heart to try to repair any damage to it, because the heart must never stop. Today, all kinds of corrective operations can be performed.

Help from the heart-lung machine

The heart-lung machine makes it possible to open the heart and operate on it without stopping the supply of blood that the body must have. The machine does what the real heart and lungs ordinarily do. It supplies oxygen for the blood, and it pumps the oxygenated blood to the body. It also does two other important things. It keeps the amount of blood and the temperature of the blood at a healthy level. Finally, it keeps the chemicals of the blood in balance.

The heart-lung machine has many parts. These are: roller pumps to keep the blood circulating; an oxygenator to supply oxygen; filters to remove any unwanted particles from the blood; a heat exchanger to keep the blood at the right temperature; a reservoir (storage place) for blood and chemical solutions; tubing, to connect the various parts, and stopcocks. The whole complicated machine is put onto wheels as one unit so that it can be moved around easily.

How it works

During surgery on the heart, the heart-lung machine takes over from the real heart and lungs. Tubes called CATHETERS are put into the main veins near the heart. From these tubes, which act like arteries, the blood flows into the machine's reservoir. It is then pumped into the oxygenator. The blood does just what it would do in the body: it gives up the carbon dioxide waste it has collected and takes in the oxygen supplied by the machine.

The refreshed blood is then passed through the filter

and the heat exchanger and pumped to a big artery through another catheter. While this system, called a bypass, is working to supply the body with blood, the heart can be operated on.

The oxygenator

The oxygenator takes the place of the blood circulating through the lungs to receive fresh oxygen. There are two kinds. One is the rotating disk oxygenator and the other is the membrane oxygenator.

The rotating disk oxygenator has many thin metal disks spaced along a shaft. This shaft is put inside a glass cylinder with metal plates at each end. The blood enters at one end and is rotated on the disks. This allows a thin film of blood to meet the oxygen contained in the apparatus.

Some disadvantages

Rotating disk oxygenators have two disadvantages. In the first place, the force set up when the blood meets the rotating disks can cause the blood cells to rupture (burst). In the second place, the direct contact of the blood with oxygen destroys some of the protein molecules in the blood. This means that the blood becomes poorer in quality. In fact, the longer the machine is used, the poorer the blood becomes. So rotating disk oxygenators can be used for only a few hours at a time without putting the patient at risk.

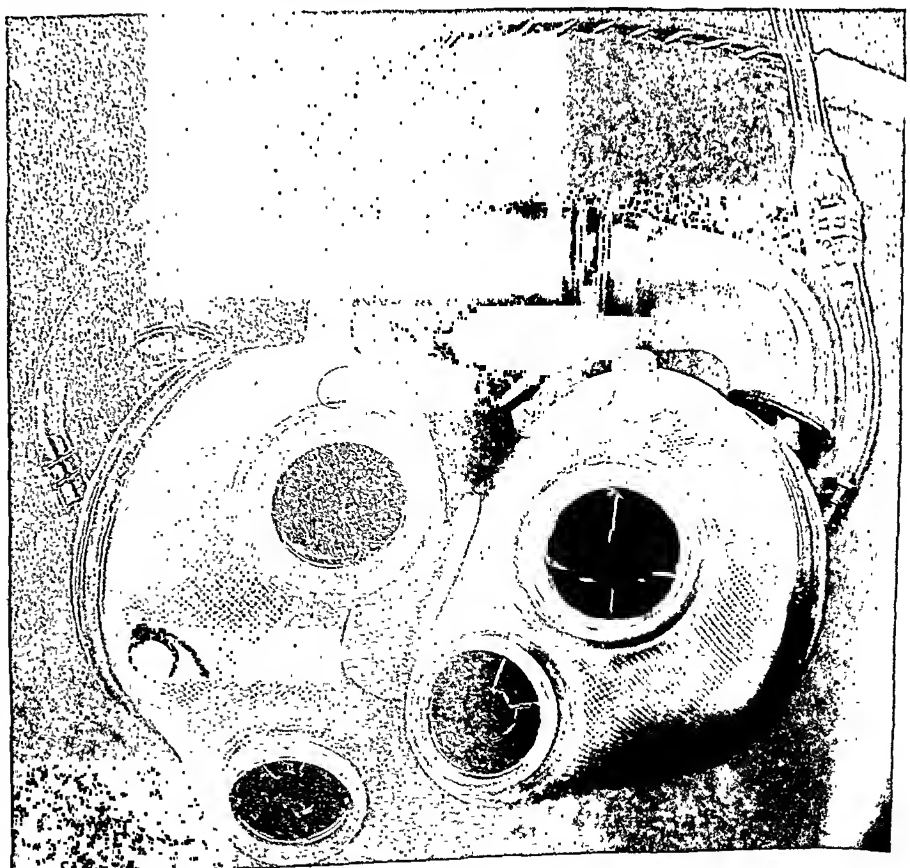
The membrane oxygenator mostly corrects these two faults. In this apparatus, the blood and the oxygen flow along opposite sides of a membrane (thin, pliable sheet), made of special rubber. Gas molecules of oxygen pass through the membrane in one direction and gas molecules of carbon dioxide pass through it the other way. So there is no direct meeting and no violent rotation.

The pump

The pump of the heart-lung machine is like the left side of the heart, and it must carry blood throughout the body without injuring the blood cells. That is why most of these mechanical pumps are designed so that their action is peristaltic (having continuous waves of contractions). The pumping rate is controlled to keep cell destruction as low as possible.

See also: **BLOOD, BRAIN, BREATHING, PACEMAKER**

Left: The repair of a human heart by the use of an artificial valve, called a Starr-Edward valve. In the left diagram, fresh blood from the lungs flows from the left atrium into the left ventricle. In the right diagram, the artificial valve closes when the left ventricle contracts, and the blood is pumped into the aorta to go into the body.



Right: An electric-hydraulic heart, which is completely artificial. It shows the structure of the real heart very clearly.

Heat Engine

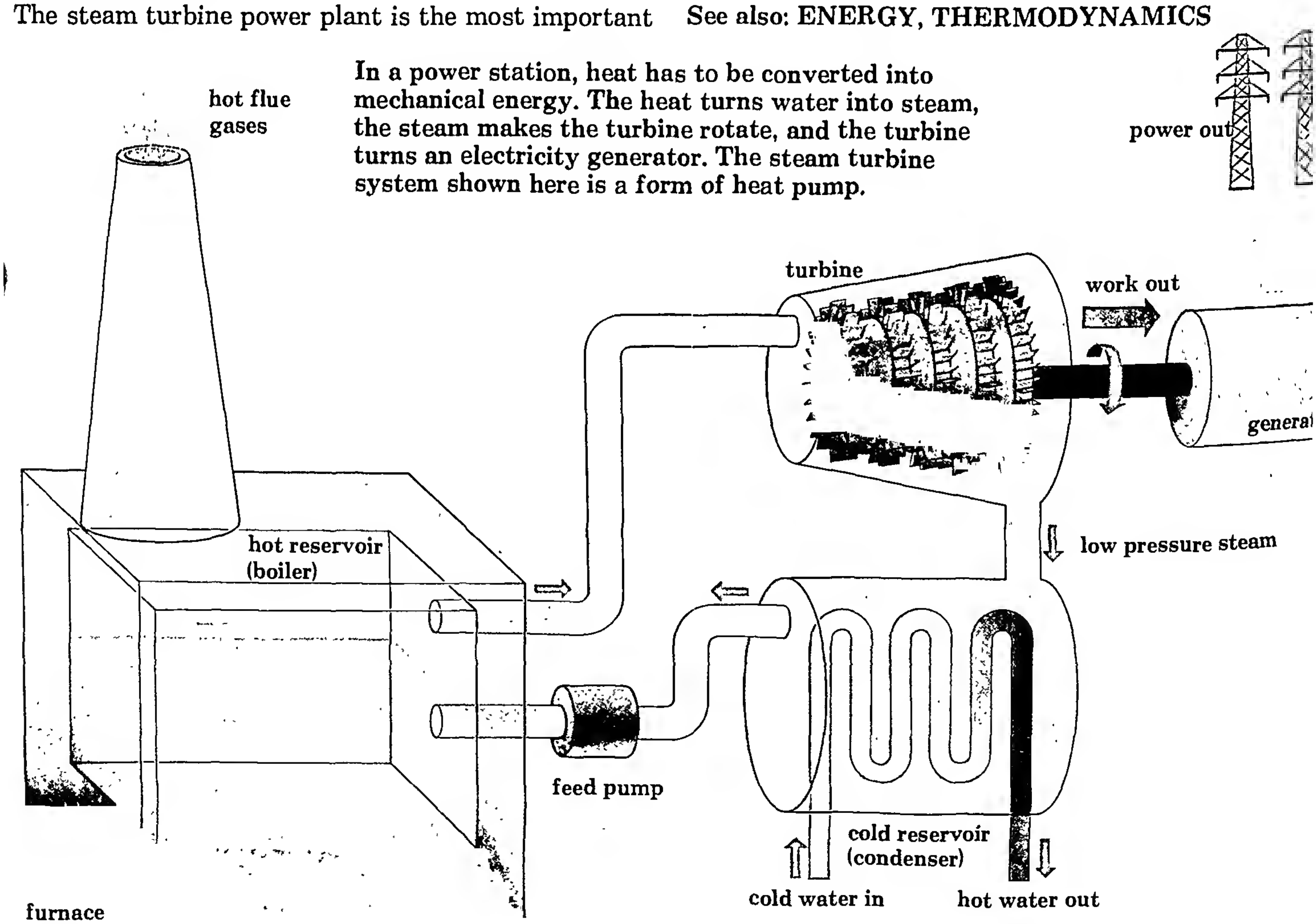
A heat engine converts heat energy into mechanical energy—that is, energy of movement. For example, in a power station, heat is used to boil water to make steam. The steam is used to turn a turbine. So the boiler and turbine together form a heat engine.

Sometimes the term heat engine is used to refer to any engine that produces mechanical energy by burning fuel. In this sense, heat engines would include gasoline engines, diesel engines and rockets. However, these take in fuel, which is then burned to provide heat inside the engines. So any such device is really an internal combustion engine. True heat engines, such as the steam turbine, are supplied with heat from outside. Other types of heat engine include the Stirling engine and the Carnot engine. In all heat engines, a substance is circulated through a series of pipes in order to transfer heat from one place to another.

Steam turbines
The steam turbine power plant is the most important type of heat engine. Water in a boiler is heated b means of a furnace. The boiler is called the ho reservoir. Steam produced here is piped to a turbine The steam passes over blades on the turbine, forcing i to turn. When the steam leaves the turbine, it passe into a condenser, a container kept cool by a pip carrying cold water. The condenser is also known as th cold reservoir. This is where the steam condenses bacl into water again. The water is then pumped from th condenser back into the boiler. The water or stean flows continuously around this closed system.

Efficiency
The efficiency of an engine is found by dividing th useful energy you get out by the energy that you put in The efficiency is expressed as a percentage. When th efficiency of a heat engine in a power station i measured, it is usually found to be around 45 percent This means that, of the heat obtained from the boiler 45 percent is converted into mechanical energy. Th rest is mostly lost to the cooling water.

See also: ENERGY, THERMODYNAMICS



In a power station, heat has to be converted into mechanical energy. The heat turns water into steam, the steam makes the turbine rotate, and the turbine turns an electricity generator. The steam turbine system shown here is a form of heat pump.

Heating

Before this century, homes were usually heated by open fires. But specially designed heaters are generally used nowadays. These produce heat from electricity, coal, coke, wood, gas, oil and other fuels. Often, one heater provides all the heat for a building. This arrangement is called central heating.

There are three ways in which heat can be transferred from a hot body (the heating equipment) to a cooler body (the building). These methods of transfer are CONDUCTION, CONVECTION and RADIATION.

Conduction

Conduction is the flow of heat from the hotter parts of a body to the colder parts, or from a hotter body to a colder body that is in contact with it. For example, the handle of a metal saucepan becomes hot by conduction when the body of the saucepan is heated.

Convection

Convection is the transfer of heat through a liquid or gas by means of circulating currents caused by the heat. Suppose, for example, that we heat a kettle of water. The bottom of the kettle becomes hot, which in turn heats the water in contact with it by conduction. The warm water, being less dense than the cooler water above it, rises to the top. Some of the cooler water descends to take its place. This, too, becomes warm and therefore rises.

In this way, continuously circulating convection currents are set up throughout the water. The heat provided underneath the kettle is, therefore, spread throughout the whole body of water.

Radiation

Radiation is the direct transmission of heat from a hot body to a cooler one some distance away. Radiation can pass through the air, and even through empty space. For example, heat and other RADIATION from the sun pass through space to reach us on earth. Radiated heat travels in the form of waves of energy, similar to radio and light waves, and moves at the same high speed.

Heaters use conduction, convection or radiation, or some combination of them, to transfer heat to a building.

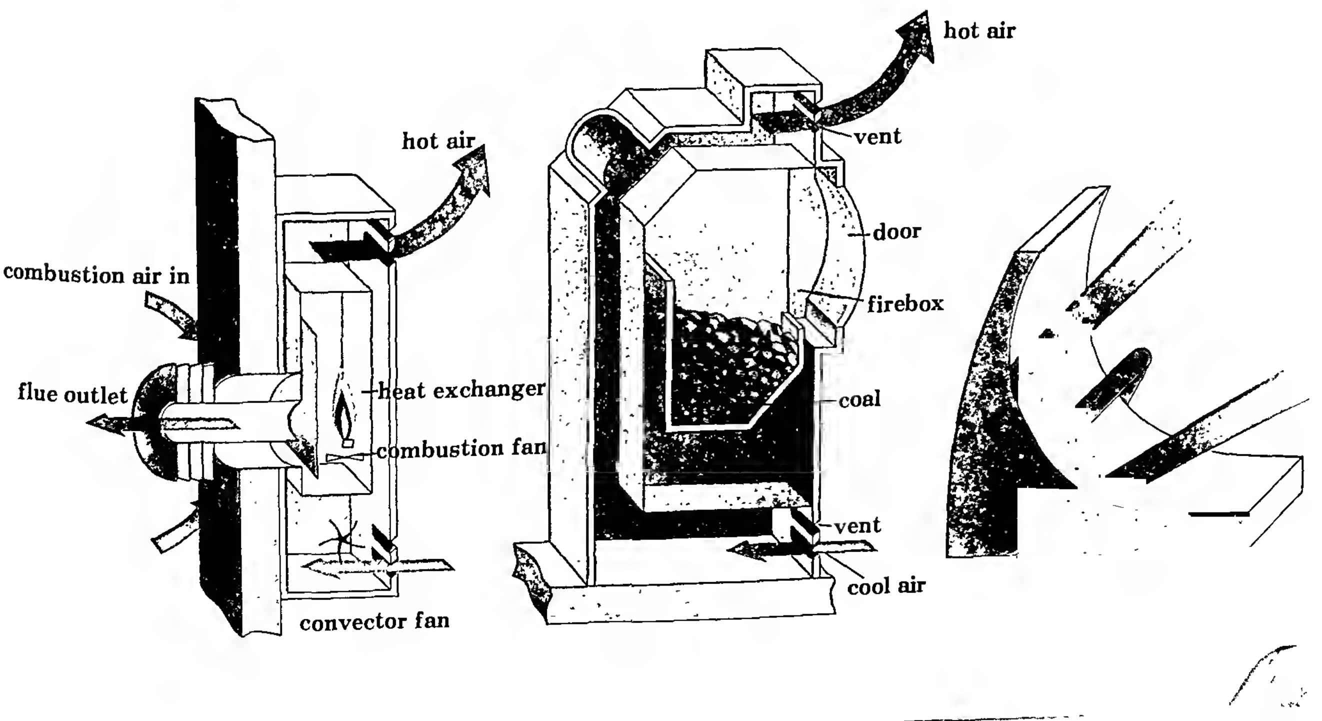
Central heating

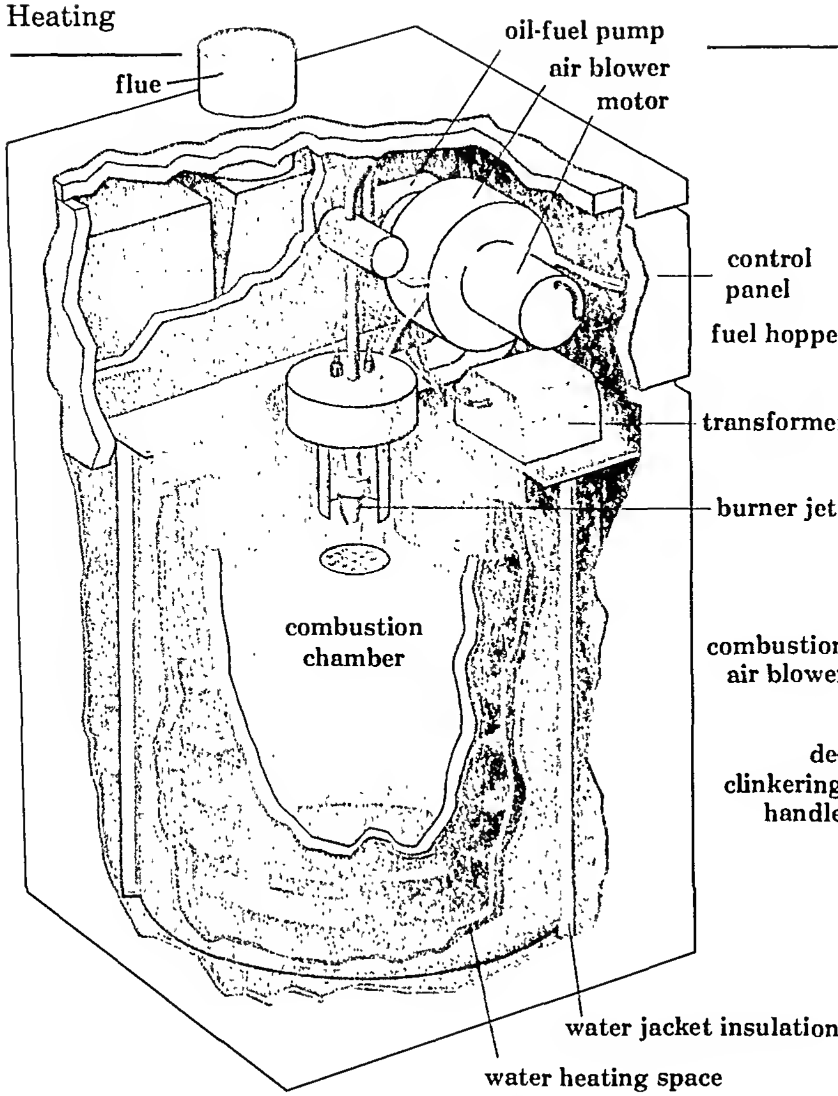
In central heating, a single heat source is used. From this, the heat is distributed around the building. The heat is carried along pipes or ducts in a flow of water or air. A BOILER is used to heat water, and a HEAT EXCHANGER is used to heat air.

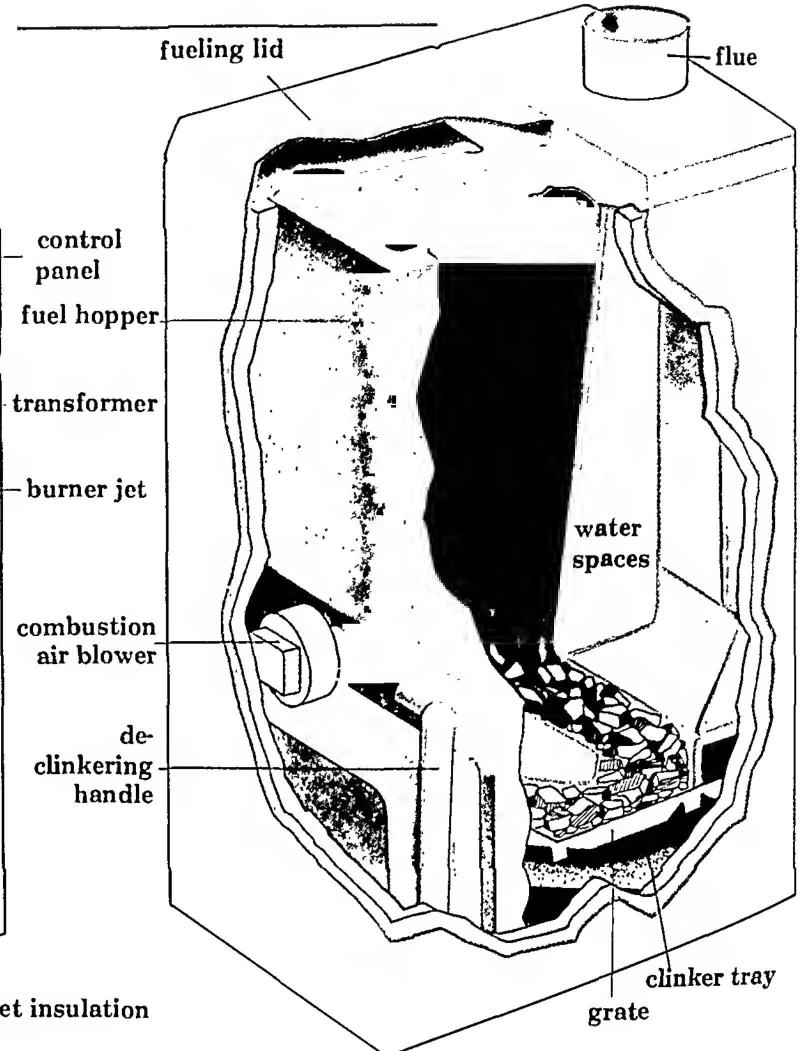
In a typical home central heating system, gas, oil or solid fuel is burned in a boiler. This transfers the heat to a body of water. It should be noted that, in spite of its name, the boiler does not boil the water, although it does make it very hot. The hot water is circulated to radiators in various parts of the house.

Radiators are simply containers with a large surface area, and water passing through a radiator will heat it.

Below: In the convector heaters, the exchangers transfer heat from the burning fuel to the air stream. The electric heater radiates heat directly to the room.







The radiator radiates some of the heat into the room. Some heat is also transferred to the room from the radiator by means of air convection currents. The radiators are connected to each other, and to the boiler, by means of piping. So the water flows from the boiler, through each radiator in turn, and then back to the boiler to be heated again.

A pump driven by an electric motor is normally used to circulate the water at a suitable rate. The system must also allow for the expansion of the water as it is heated. In an open system, the extra water volume is taken up in an open expansion tank. In a sealed system, a closed expansion vessel is used. This normally contains air, which becomes compressed when water enters.

In a warm air central heating system, the fuel heats a device called a heat exchanger. A fan forces air through or over the heat exchanger, so some of the heat is transferred (passed on) to the air. The warmed air is distributed through ducts to the rooms. It enters each room through a grille, circulates around the room, and then passes out through another grille. The air then goes back to the heat exchanger for reheating. Air from outside the house may be introduced into the system through a fresh-air inlet for ventilation.

Above left: A pressurized jet oil boiler. The pump provides the necessary oil pressure.

Above: A coal boiler, with the fuel fed in automatically by gravity.

Boilers
In a domestic boiler, the part where the fuel burns is called the COMBUSTION zone. The water passes through a container next to the combustion zone. The container has a large surface area. This ensures that the maximum amount of heat is transferred to the circulating water.

Solid fuel boilers
In solid fuel boilers, the fuel is fed in from a hopper above the combustion zone. The air required for burning is sometimes blown in beneath the grate of the boiler by means of a fan. Solid fuel boilers require a brick chimney or a well-insulated flue pipe to remove

the fumes from the burning fuel. Some small central heating systems use solid fuel burnt in an open fire. Water is heated by passing it through a tank at the back of the fire. An arrangement of this kind is called a back boiler. Gas or oil heaters are sometimes fitted with back boilers, too.

Gas boilers

In gas boilers, the gas is fed to a series of jets in the combustion zone. A permanently lit pilot jet is used to IGNITE the gas coming from the main jets when this supply is switched on. Air for combustion is drawn from the room in which the boiler is located, or from outside through a tube.

Oil-fired boilers

In oil-fired boilers, the oil can be burnt in one of three ways, according to the type of burner used. With a VAPORIZING burner, the oil flows along a supply pipe and into a burner pot in the boiler. Air for combustion is drawn in, or blown in by a fan, along a draft tube positioned around the oil supply pipe. The burning oil soon heats up the burner pot. This causes the incoming oil to turn to VAPOR, just before it burns.

In PRESSURIZED burners, oil is pumped to a nozzle. It emerges as a fine spray. A fan blows in air, and the oil is ignited by a spark.

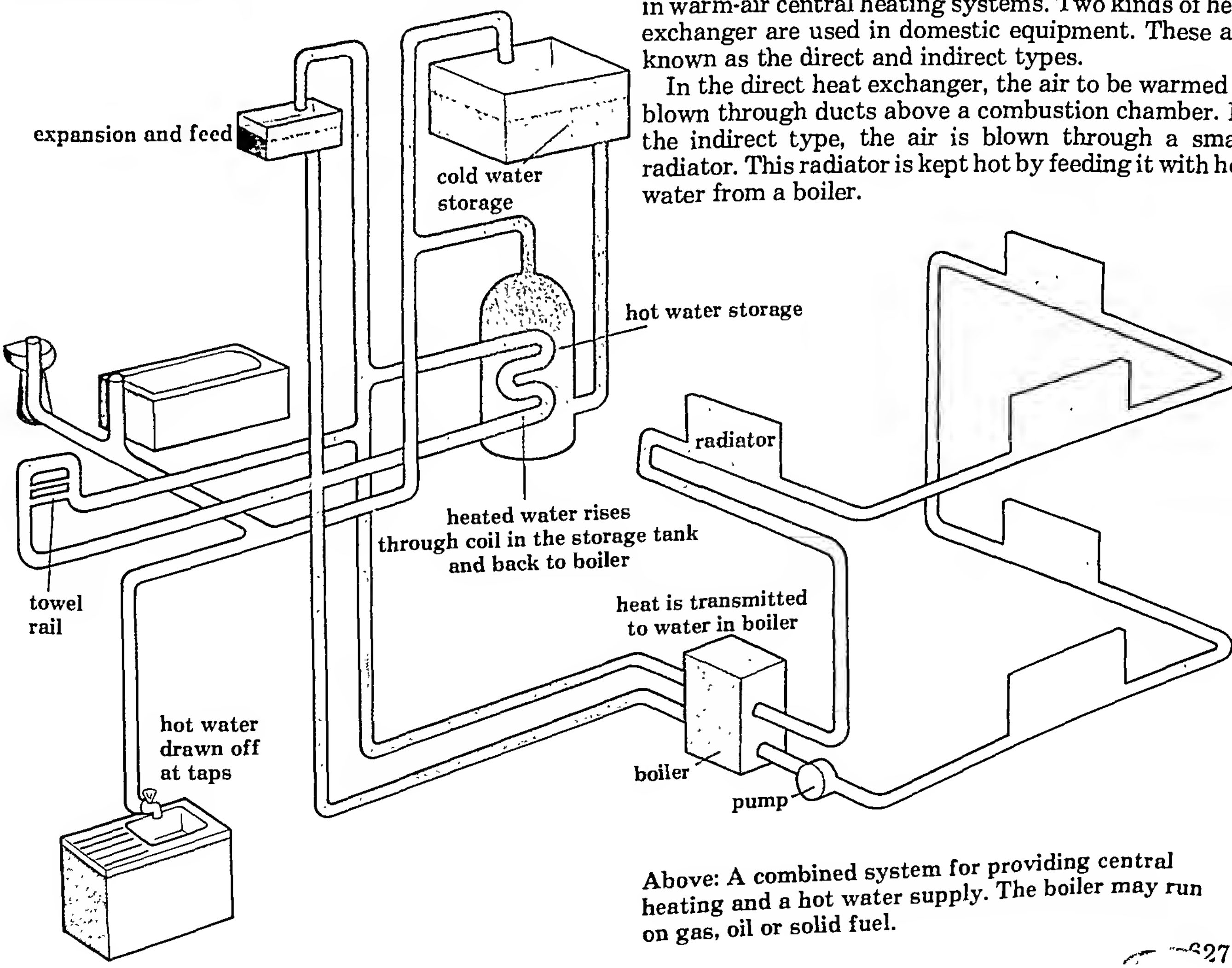
In rotary burners, the oil is fed onto a spinning oil cup in the boiler. Air for combustion is blown in by a fan. The spinning cup throws oil droplets outward onto a burner ring. There, the oil is ignited electrically. Once the ring has heated up, the oil stays alight without electrical assistance.

The flame produced by a rotary burner is cylindrical in shape, and wipes the walls of the boiler. For this reason, rotary burners are sometimes called wall flame burners.

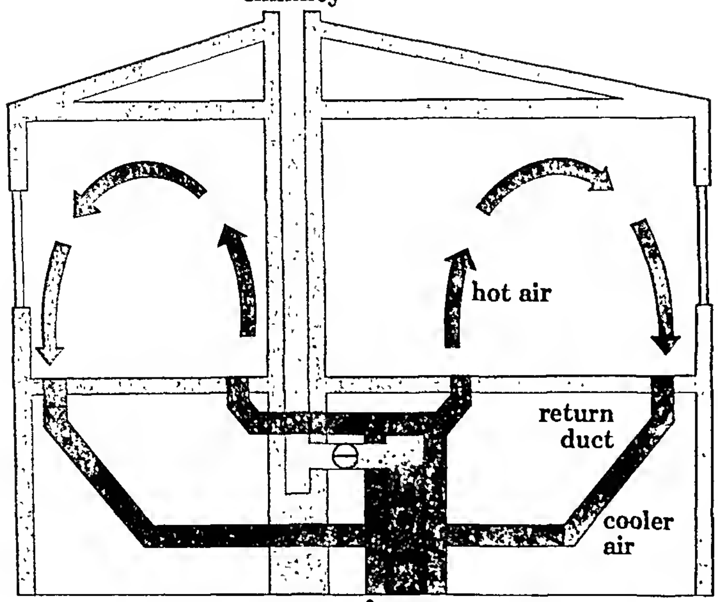
Heat exchangers

Heat exchangers are used to convey heat to the air used in warm-air central heating systems. Two kinds of heat exchanger are used in domestic equipment. These are known as the direct and indirect types.

In the direct heat exchanger, the air to be warmed is blown through ducts above a combustion chamber. In the indirect type, the air is blown through a small radiator. This radiator is kept hot by feeding it with hot water from a boiler.



Above: A combined system for providing central heating and a hot water supply. The boiler may run on gas, oil or solid fuel.



Above: A warm-air central heating system. Cool air picks up heat from the furnace via the exchanger and carries it to the rooms.

Storage heaters

In some countries, electricity is available at a cheap rate if it is used at times when demand is low. This is mainly at night. To take advantage of this "off-peak" electricity, special storage heaters are used. These use the cheaper electricity to produce heat, which is stored until it is required. Storage heaters are made for use in central heating systems, and also as separate units for individual room heating. Both types usually have electrical heating elements inside blocks of special clay. Heat produced in the elements is stored in the clay. A thick layer of heat insulating material around the clay prevents the heat escaping.

In central heating systems, water can be pumped through a coiled pipe in the clay to remove heat when required. Alternatively, air can be passed through the clay to pick up the heat. This can be transferred to the water by means of a heat exchanger. Or the air may be used in a warm-air heating system.

Electric room heaters

The simplest electric storage heaters used in individual rooms have no controls. The clay simply gives out its heat to the room throughout the day. Nothing can be done to prevent further heating when the room becomes too hot. Better types of heater allow air convection currents flowing over the clay to be regulated. So the rate at which the clay gives up its heat can be controlled to some extent. The best type of storage heater has an electric fan to blow air through it. The rate at which heat is given out can be varied by altering the speed of the fan.

In radiant electric heaters, a current passing through one or more coiled wire elements makes them glow red hot. The heat is radiated directly into the room from the elements. A polished metal reflector behind the elements helps to direct most of the heat toward the front.

In an electric convector heater, the element operates at a lower temperature. It is mounted in a housing with an air inlet at the bottom and an outlet at the top. Air near the element is heated so it rises and passes out at the top. It is replaced by cooler air drawn in at the bottom. The air convection current set up in this way circulates heat throughout the room.

Fan heaters are similar to convector heaters, but differ in that the air is forced past the elements by means of an electric fan. Fan heaters can, therefore, bring a cold room up to a reasonable temperature more quickly.

Oil-filled electric radiators have a heating element at the bottom. This heats oil, which circulates inside the radiator. The radiator's large surface transfers heat efficiently to the surroundings.

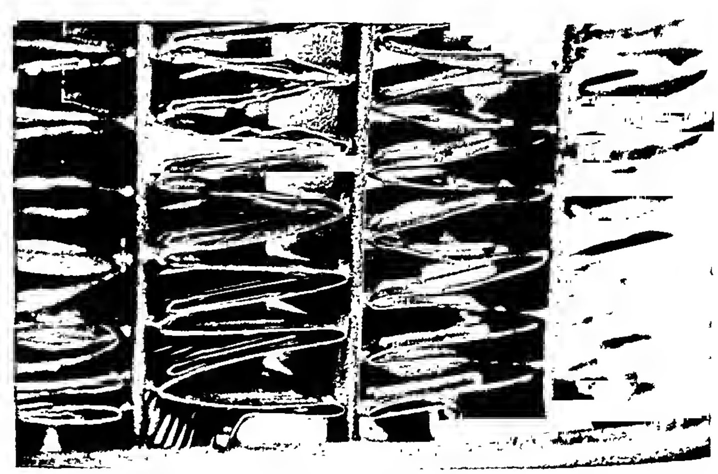
Oil and gas heaters

Oil heaters, which burn kerosene, are very cheap to run. These usually have a wick at the base of a chimney tube. Kerosene soaked up by the wick burns to produce heat.

Radiant gas heaters have gas jets, which heat elements around them. The red-hot elements radiate heat to the room. Gas convector heaters have a heat exchanger, which transfers heat from gas jets to a current of air passing through the heater.

See also: ELECTRICITY, ENERGY, HEAT PUMP

Below: Hot liquid passes through the tubes of this heat exchanger. Air blown over the pipes picks up some of the heat.



Heat Pump

Normally, heat can flow only from a hot body to a cooler one. A heat pump is a device that causes heat to move in the opposite direction. In other words, it can "pump" heat from a cold body to a hotter one. To do this, the pump must be supplied with some form of power.

The term heat pump is somewhat misleading. Although we often talk of a flow of heat, it is not a fluid like water or air, and so cannot really be pumped. Instead, a fluid that carries the heat is pumped around.

Working principles

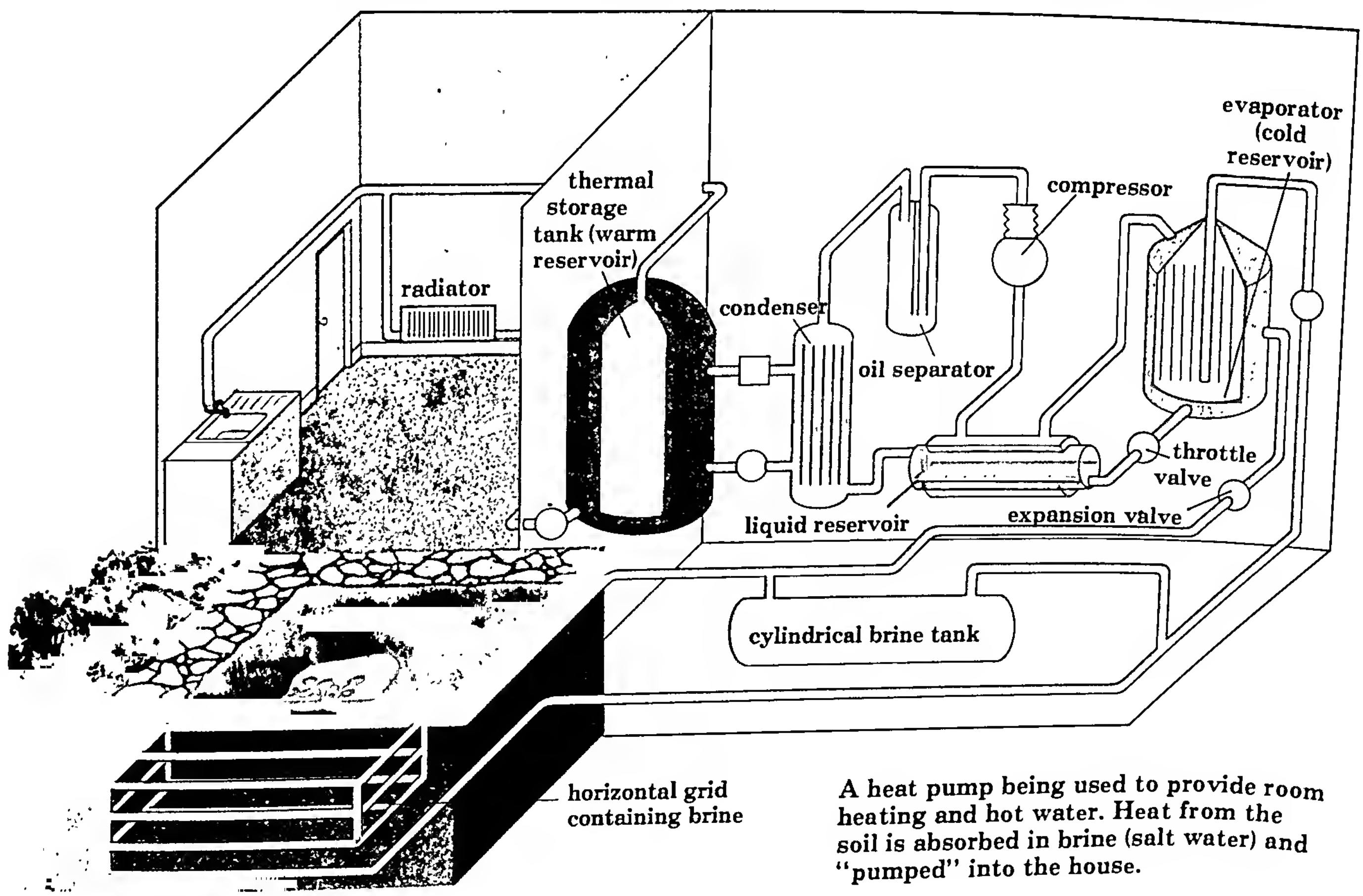
A heat pump works like a refrigerator. The only difference is in the purpose. Heat from inside a refrigerator is pumped to the outside and radiated away. Here, the object is to keep the inside of the refrigerator cool. The main purpose of a heat pump is to provide useful heat. So here, we are more interested in what happens to the heat, rather than how cold the heat source itself becomes.

The heat pump consists of a closed system of pipes and containers. A fluid is driven around the system by a pump. The fluid enters the pump as a VAPOR and undergoes a rise in pressure and temperature. The vapor passes through a CONDENSER, which converts it to liquid. In this process, the vapor gives up its heat, which is then transferred to a storage tank.

The liquid from the condenser flows into a liquid reservoir, and then through a throttle valve. The liquid spurts through this narrow passage into a low-pressure area. The reduction in pressure causes the liquid to partially vaporize, and its temperature is reduced. Then the cooled liquid–vapor mixture passes through an evaporator in the cold reservoir. Because it is colder than the cold reservoir, the mixture takes in heat from the cold reservoir and leaves at a higher temperature.

The whole cycle then repeats, the fluid passing heat to the storage tank each time. From here, the heat can be distributed to radiators in the usual way. The evaporator must be supplied with heat from an outside source. For example, a liquid passing through pipes outside the house can be used to pick up heat. The liquid is then passed through pipes in the evaporator, where the heat is absorbed.

See also: **HEATING, THERMODYNAMICS**



A heat pump being used to provide room heating and hot water. Heat from the soil is absorbed in brine (salt water) and "pumped" into the house.

Heat Treatment

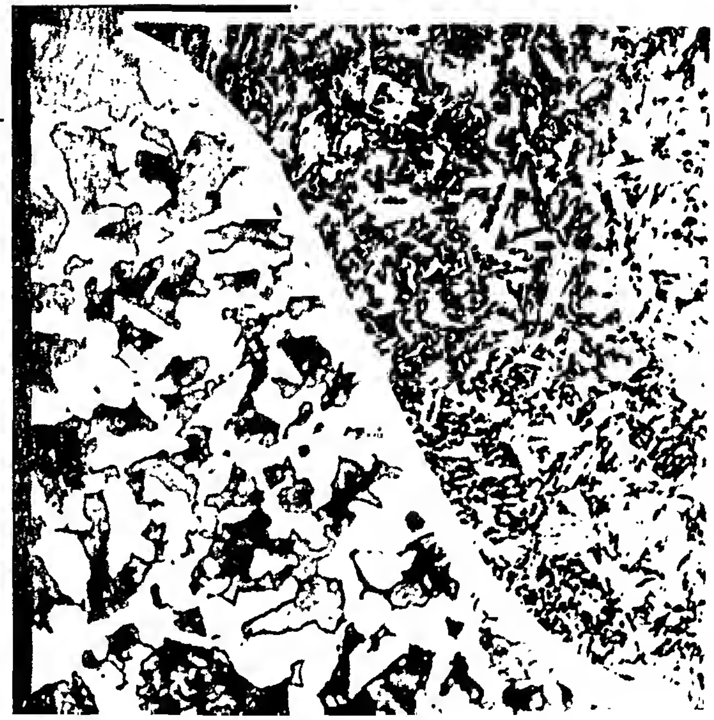
Heat treatment covers a number of processes in which metals and alloys are heated and cooled in order to change their properties. When metal is heated, the arrangement of the atoms that make up the metal often changes, causing the metal to behave differently.

The arrangement of the atoms in a metal is what gives the metal its hardness, strength, toughness and ease of being worked and machined. In changing the arrangement of the atoms by heat treatment, the most important factors are the make-up of the metal itself, the rate at which it is heated, the temperature to which it is heated, how long it is kept at that temperature and the rate at which it is cooled.

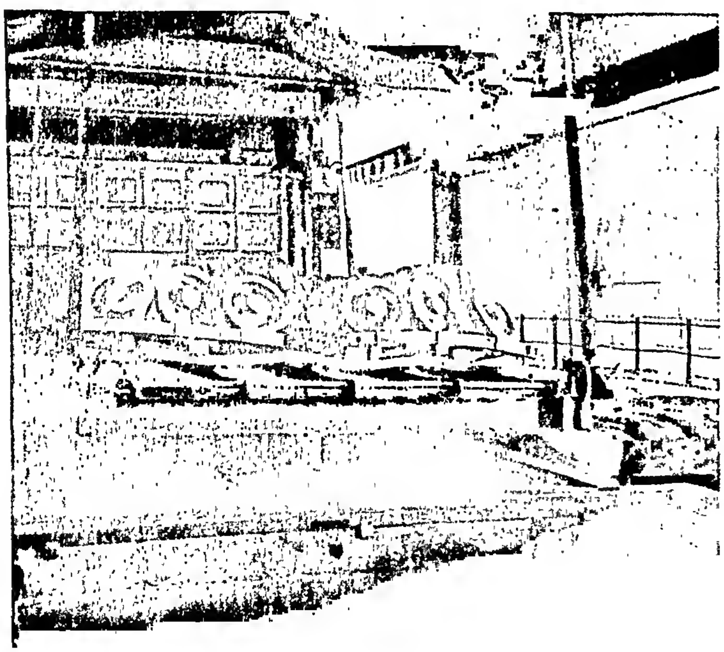
In the furnace

Most heat treatment is carried out in specially designed furnaces. These furnaces may have different temperature areas in them so that the metal can go from one temperature to another within the furnace. Cooling may take place inside the furnace or outside.

Steel is the most important metal that is involved in heat treatment. The three main processes of heat treatment are ANNEALING, HARDENING and TEMPERING.



Above: When steel is heated and cooled slowly, the tiny granules in the metal look like those on the left. The steel is neither hard nor brittle. If the steel is plunged into water, the granules become small and needle-like (right). The metal is hard and brittle.



Annealing

When metals are annealed they are heated to a temperature below their melting point and allowed to cool slowly. This reduces internal pressures called stresses. These stresses are often caused by machine operations on the metal. This is why annealing is often carried out after the metal has been machined.

Hardening and tempering

Steel can be made very hard by heating it to a high temperature and then plunging it into a tank that contains oil, water or brine (salt water). This is called quenching.

Because hardening steel also makes it brittle (easy to break), it is usually tempered after it has been hardened. Tempering makes the steel tougher. In tempering, the metal is heated to a temperature that is not as high as that for hardening. Then it is cooled slowly so that it reaches the required degree of toughness and hardness without becoming brittle.

Typical objects that are hardened and tempered are seat belt buckles, bolts, springs, wrenches, crankshafts and gun barrels.

See also: BLAST FURNACE, IRON AND STEEL

Left: A load of metal castings is being taken from the furnace to be plunged into an oil quench tank.

Helicopter

Helicopters can do what no other aircraft can, and can go where other aircraft cannot. They can hover in midair, fly backward and sideways, or go straight up and down. They can land on a rooftop or in a backyard. But they do not travel at high speeds, and so are not used for long-distance flights.

Helicopters have many uses based on their ability to fly in all directions and to land in very small and very rough areas. For example, they are used for air-sea rescue work, when they sometimes have to hover over one place to pick up people, or land on the deck of a moving ship. They can also land on the water by means of inflatable (able to be blown up) bags, which act as floats to keep the machine on the surface for a time.

Helicopters at work

This maneuverable (easy to handle) aircraft has won favor in many cities for traffic control from the air. A helicopter surveys the traffic flow and reports the state of affairs to the traffic center. Farmers have found them good for sowing crops, and fire departments put them to use to reach difficult places in fighting fires. Off-shore oil rigs often depend on helicopters to bring them supplies.

There is a heliport right in the middle of New York City on the roof of a tall building near the Grand Central Terminal. At one time, helicopters provided a taxi service from here to airports in the New York area.

Unlike other aircraft, helicopters do not need a runway to take off and land. That is why a heliport can be on a rooftop. They go straight up into the air to take off, and come straight down to land.

The great maneuverability of helicopters explains why they were used as ambulances, troop transports, and reconnaissance aircraft in the rugged jungles of Vietnam during the fighting there in the 1960s.

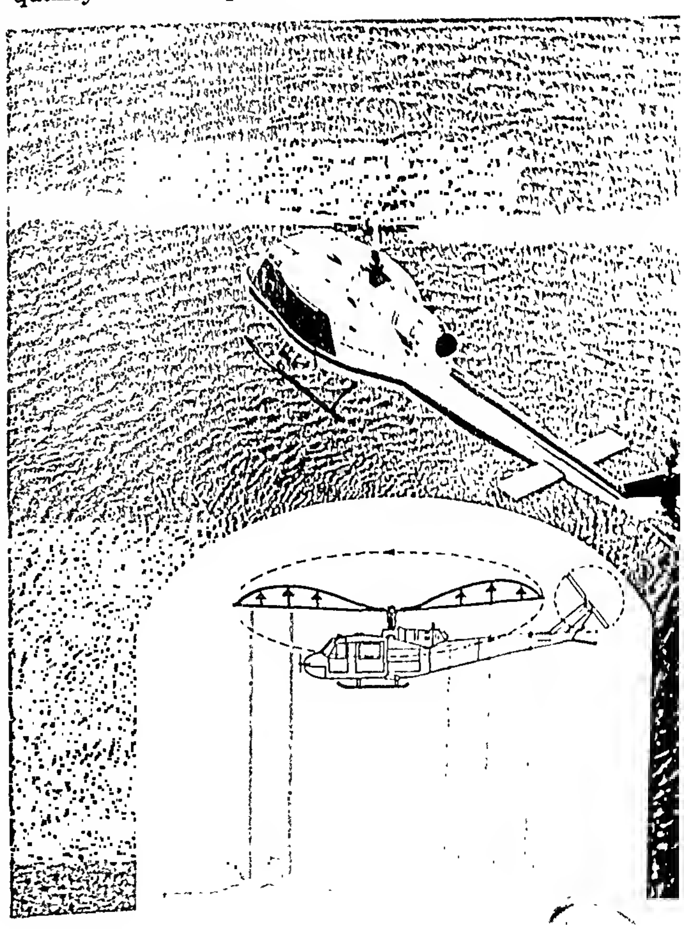
Whirling wings

A helicopter looks like a small plane with a big fan on the top. This fan is really a group of blades, each of which is like a thin wing. These blades together make up the rotor, which can have from two to seven of them. The rotor whirls to give the machine movement, and it is this fanlike rotation that has given the helicopter the nickname of whirlybird. The word helicopter comes from the Greek words that mean rotating wings.

The wing blades are hinged near where they are attached to the center of the rotor so that they can flap a little. This is because the blades have to rise when the machine is moving forward and drop when it moves backward, in order to keep the lift force equal on both sides of the blade.

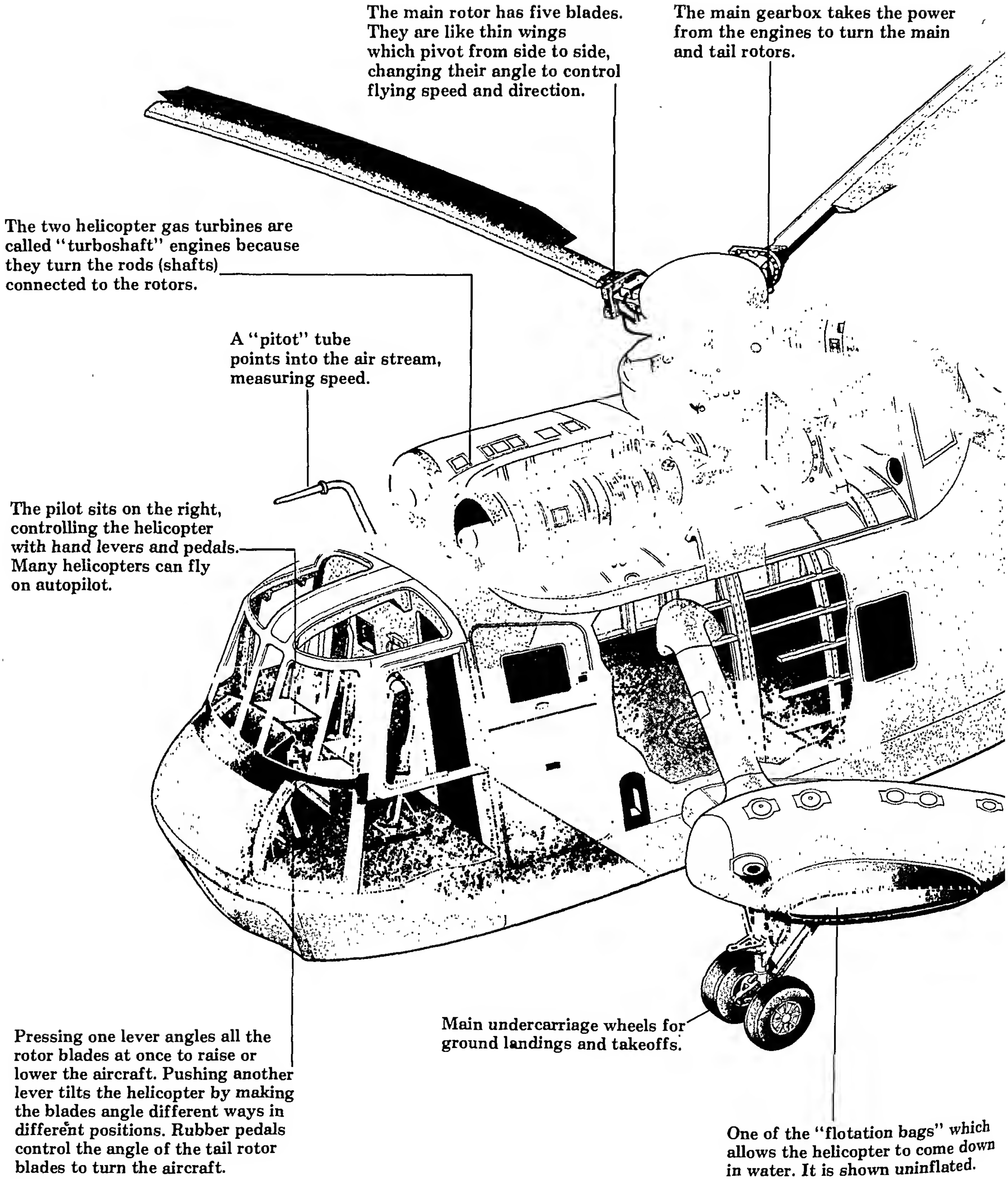
The whirling of the rotor is strong enough to twist the small machine around in circles. This is prevented, however, by putting a smaller rotor in the tail of the helicopter. The tail rotor rotates vertically (in an up-and-down direction). This is opposite to the top rotor, which rotates horizontally (in a flat position). The vertical whirling of the tail rotor cancels out the possible twist of the top rotor.

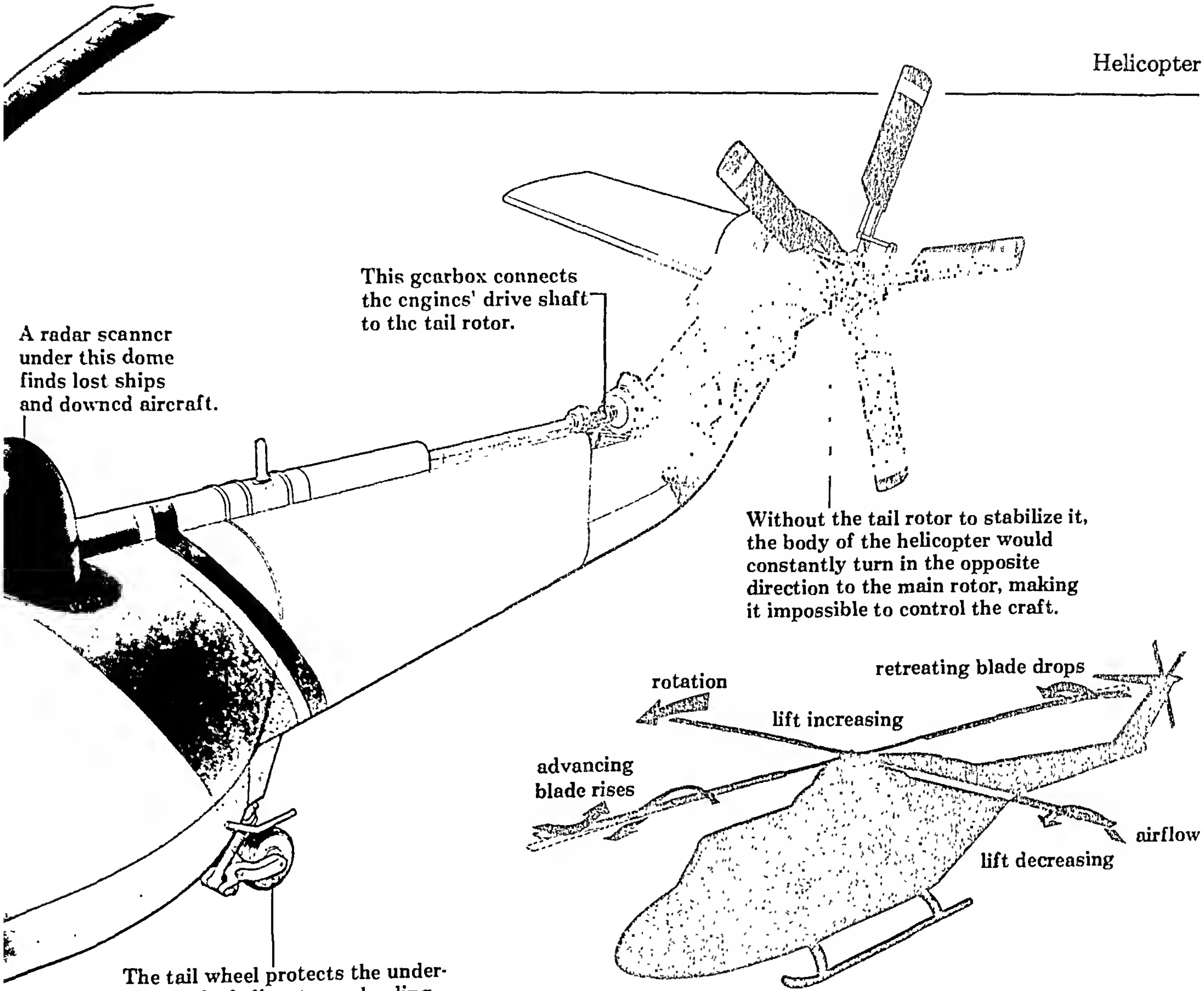
A helicopter flies at about 250 miles (400 kilometers) per hour. This is very slow compared to large passenger planes, and is why helicopters are used mostly for short hops. If the engine of a helicopter fails, the craft will still be able to land. This is done by changing the position of the rotor blades to keep them spinning. The ability to land without an engine is another good quality of a helicopter.



Right above: A helicopter seen from above shows the pattern caused by the down draft on the water below. It is the air being forced down that gives the helicopter its lift.

Right: The arrows above the rotor blades mark the points at which the down draft of a helicopter is the strongest.


The main rotor has five blades. They are like thin wings which pivot from side to side, changing their angle to control flying speed and direction.
The main gearbox takes the power from the engines to turn the main and tail rotors.
The two helicopter gas turbines are called "turboshaft" engines because they turn the rods (shafts) connected to the rotors.
A "pitot" tube points into the air stream, measuring speed.
The pilot sits on the right, controlling the helicopter with hand levers and pedals. Many helicopters can fly on autopilot.
Pressing one lever angles all the rotor blades at once to raise or lower the aircraft. Pushing another lever tilts the helicopter by making the blades angle different ways in different positions. Rubber pedals control the angle of the tail rotor blades to turn the aircraft.
Main undercarriage wheels for ground landings and takeoffs.
One of the "flotation bags" which allows the helicopter to come down in water. It is shown uninflated.



Left: A diagram of a helicopter showing all its parts. This helicopter can land and take off on any surface including water.

Above: The rotor blades flap upward when they move toward the front of the machine and downward when they are moving to the rear. This makes the lift equal on both sides.

Going up and coming down

The rotor is driven by an engine and controlled by a single lever in the cockpit. After the engine has powered the rotor, the lever is moved to turn the angle of the blades slightly upward. This combination of the rotation and the angled blades lifts the helicopter. The machine goes up into the air because the total lift created by the rotor is greater than the weight of the machine itself.

To make the helicopter come down for a landing, the lever is moved so that it turns the blades to angle downward. This reduces the lift that the rotor gives to the machine, and slows it down for the descent and landing.

Standing still in midair

Helicopters are the most like birds of any aircraft because they can hover in midair. To make the machine stay in one spot, while still in the air, the lever is kept in the middle position. This makes the weight of the machine exactly equal to all the lift forces acting on the rotor, and keeps it in one place.

Moving in all directions

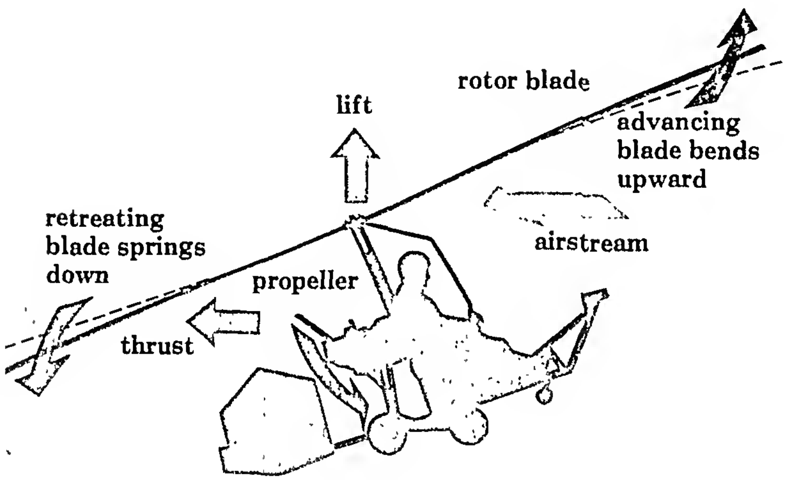
To understand how a helicopter moves forward, backward, and sideways left or right, try to think of the rotor as a disk. If the blades in the front half of the disk are tilted forward slightly, the rotor will pull the machine forward. If the rear half of the disk is tilted backward, the machine will move in that direction by

the rotor's action. If either one side or the other of the disk is tilted, the helicopter will go to that side.

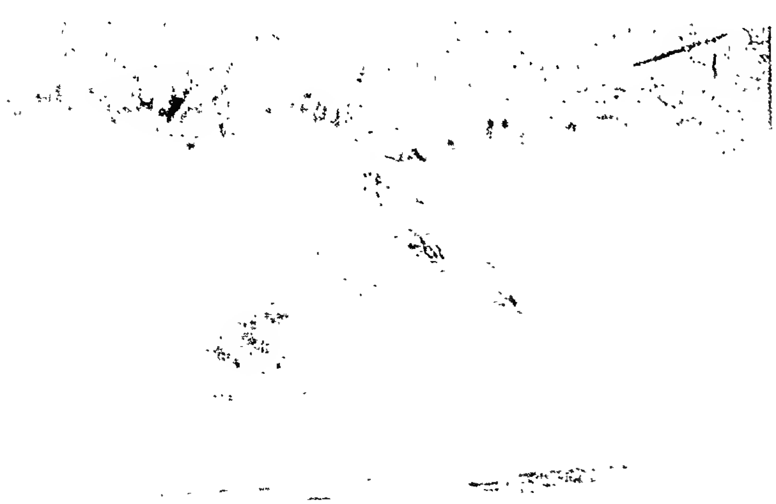
Not swift as a swallow

The reason that helicopters cannot fly at a great speed is that there is a difference in the air speed of the forward-moving and the backward-moving blades. At high speeds, the forward-moving wings come near to the speed of sound, while the backward moving wings keep only a very low speed. This creates a heavy drag on the forward-moving blades, so that they begin to lose their lift. The backward-moving blades lose lift simply because of their low air speed. So, if the helicopter tries to go too fast, the blades will stall.

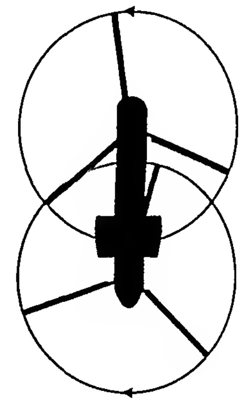
One idea to make helicopters go faster is to use two identical rotors, one on top of the other. Each would

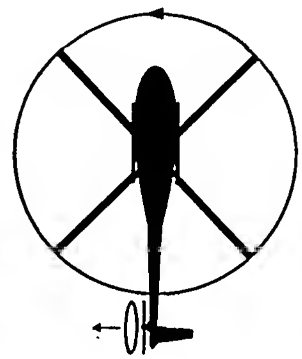


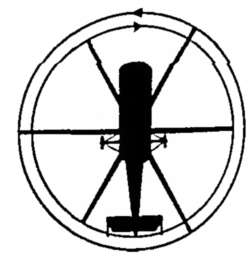
Above: An autogyro has a much flimsier body than a helicopter. It is also different in having a propeller and in being steered by a rudder. On takeoff (below), the autogyro must move forward, and so it requires a short runway.

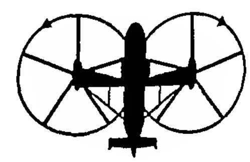


These illustrations show how the body of a helicopter is prevented from twisting with the force of its rotor. The twist can be offset with two main rotors turning in opposite directions (top and bottom right). These two rotors can also be placed one above the other (center). A small tail rotor is the most common way to keep the body from twisting around (below).









turn in the opposite direction, which would reduce the drag on the forward-moving blades. It would also increase the lift on the backward-moving blades.

History

One of the earliest designs for an aircraft like a helicopter was made by Leonardo da Vinci in the 16th century. This great artist and inventor seemed to be able to look into the future, and he described many machines that we use today. But he seldom tried to make his ideas work. Practical experimenters, such as Louis Breguet (1880–1955) and Juan de la Cierva (1885–1936), were aeronautical engineers who actually built machines. In fact, de la Cierva made a successful flight with his autogyro in 1923 in Spain. The autogyro is closely related to the helicopter, but must have a short runway for the takeoff. It also has a propeller behind the cockpit, in addition to the rotor.

The person who did the most to perfect the helicopter and to bring it into use was Igor Sikorsky (1889–1972). In 1941 he established the world record for sustained (nonstop) flight in a helicopter of his own design and construction. He was interested in all kinds of aircraft, but he is best known for his success with the helicopter.

See also: AIR CUSHION VEHICLES, AIRFOIL, AIRPLANES, PROPELLER

Hi-Fi Systems

Above: Testing loudspeakers in an anechoic chamber, a special room designed to be without an echo.

Hi-fi" is short for "high fidelity." The term s used because a hi-fi system tries to eproduce sounds with as much fidelity, or aithfulness to the original, as is possible. The ery best hi-fi equipment can make music ound almost as it sounded in the concert hall r recording studio.

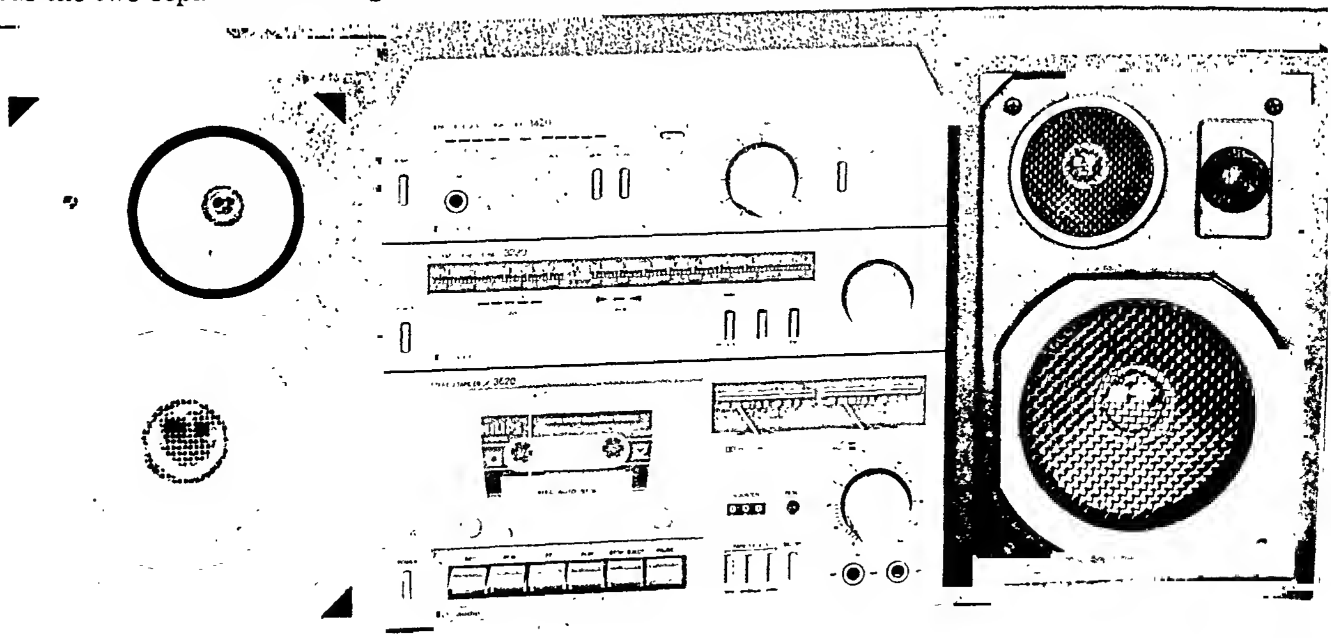
)ur ears can hear sounds with frequencies that are oughly between 20 and 20,000 Hz (20 and 20,000 ound waves per second). The ideal hi-fi system should, herefore, be able to reproduce all these frequencies qually well. It should reproduce loud tones as clearly s soft tones, and it should not produce any sound or ioise that was not in the original.

A hi-fi system is made up of three main parts. The irst part consists of a radio tuner, a tape deck or a ecord deck. The second part is an amplifier. The third s a speaker system, usually consisting of at least two peaker units for stereo sound.

Stereo

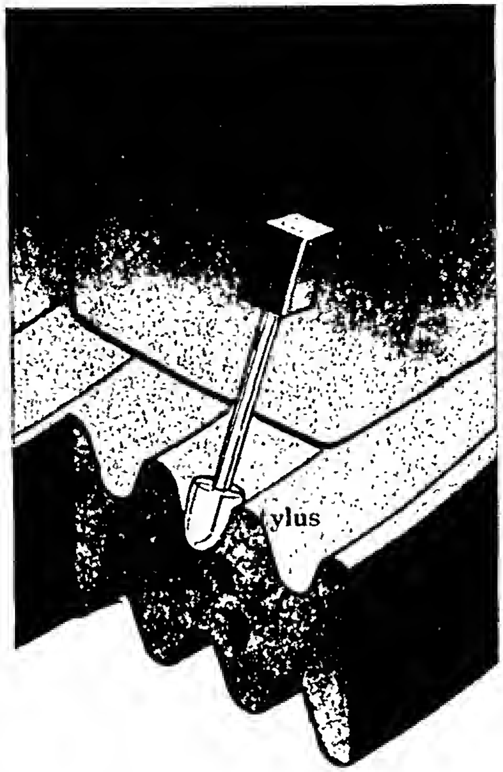
Iowever much a sound system is improved, eproduction from a single loudspeaker can never ound completely natural. All the sound comes from ne direction, whereas sound normally comes to us rom various directions. This problem can be partly vercome by a stereophonic sound system. In this ystem, two separate microphones are used to pick up ound from different angles in the studio or concert iall. The hi-fi source at home—radio, record or tape—eeds the two separate sound signals to the amplifier.

Below: A hi-fi stereo system for tape and radio reproduction. Each loudspeaker has three units: "woofer," "squawker" and "tweeter."

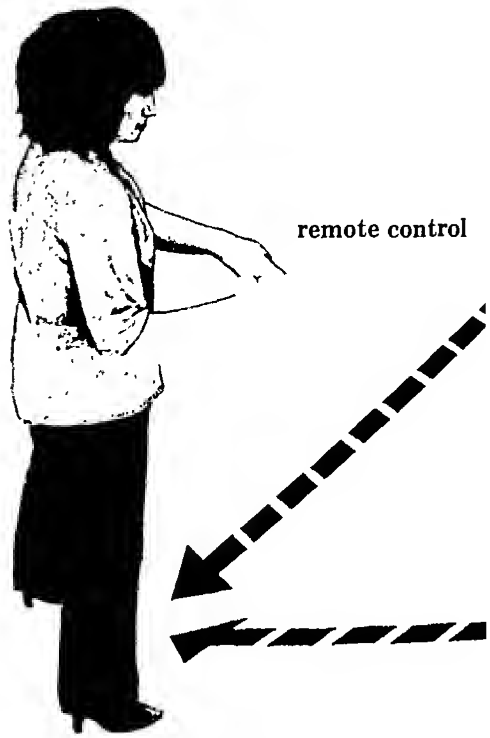


Right: As the stylus travels along the record groove, variations in the groove make it vibrate. This, in turn, causes the magnets in the cartridge to vibrate and sets up a current in the coils. This current is passed to the amplifier.

Below: A magnetic cartridge showing the stylus, coil and magnet. The more accurately the cartridge translates the vibrations of the stylus, the better the quality of the sound.



A hi-fi system, showing the connections between the tuner, tap deck, turntable, amplifier and loudspeakers. Modern systems can incorporate remote control.



These are then fed to two separate loudspeaker units. The sounds that come from one speaker are quite different and separate from the sounds that come from the other. In this way, our ears receive sounds similar to those that would be heard in the studio.

Most hi-fi systems either combine the amplifier as part of the turntable unit or as a separate single unit.

The amplifier

The amplifier is at the heart of any hi-fi system. It detects the required input, whether from a record, tape or FM radio, and amplifies it (makes it stronger). The input signal has to be amplified until it is strong enough to power a pair of loudspeakers. The tiny input may be only one-thousandth of a watt and this has to be amplified to 10 or more watts.

In the last 10 years, transistors have produced a revolution in hi-fi amplifiers. The thermionic tubes they replaced were big, often noisy and expensive. Transistors are tiny, quiet and give a lot more power at quite low cost.

The way that amplifier circuits treat the incoming signals can cause unwanted noise and distortion of the sound. But enormous amounts of time and money have gone into designing amplifiers that produce true, distortion-free sound. Some designers have ev suggested that the old thermionic tubes, or their new offspring, are better for some parts of the circuit.

The amplifier has bass and treble controls to balan the sound reproduced. By emphasizing the high or lc frequency output, tinny high notes or boomy low not can be reduced.

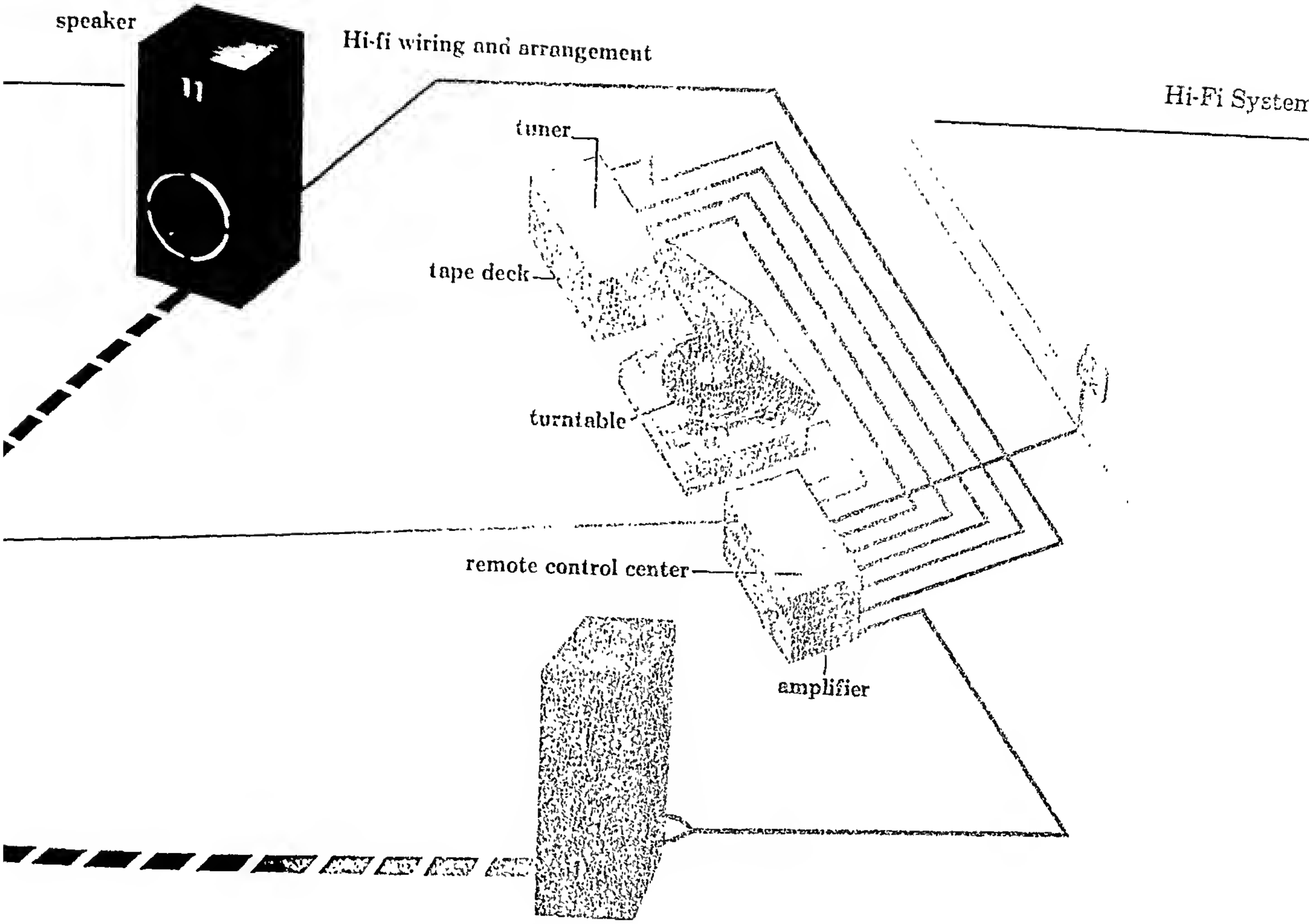
Record decks

Record decks consist of a turntable that spins tl record, a pickup arm, and a cartridge which mak contact with the record and turns the bumps in tl record groove into electrical signals.

The turntable rotates at a fixed speed, powered by ε electric motor. For LP (long-play) disks and some 7-inc singles it revolves at 33⅓ r.p.m. (revolutions p minute). For most 7-inch records, it rotates at 45 r.p.r

The drive system to the turntable must operat silently and keep an even speed. Noisy drive motors ca produce unwanted "rumbles." In some models, th turntable is turned by a high-speed motor, operating rubber belt through a system of pulleys. Direct-drive turntables are also used, the shaft of the motor bein connected directly to the turntable.

The pickup arm holds the cartridge in place as i passes across the record. In addition to moving easil



across the disk, it has to exert the correct tracking (downward) force. The arm can be adjusted by a counterbalance weight at the end.

Pickup arms are usually shaped like a "J" or an "S." But arms of this kind have some tracking error because, being pivoted, they do not follow a straight path across the record. When a disk is being recorded, the cutter head takes a straight path across it. This path will produce least tracking error, so record decks are now being produced with tracking arms that move across the disk in a straight line. This special kind of tracking arm is, however, complex and expensive to manufacture.

The cartridge

The cartridge is the most important part of the record deck. It is the cartridge that makes contact with the disk and produces the electrical signal that is fed to the amplifier. The cartridge and its stylus (needle), which runs in the record groove, work in a strange world that can only be seen properly under the great magnification of powerful microscopes. The tiny stylus traces signals smaller than the wavelength of light and vibrates at a fantastic rate. It can cause distortion by rattling in the groove or wandering from the correct groove path. The old lightweight aluminum stylus bar has given way to tubes made of boron crystal. The stylus itself may be diamond. One manufacturer even uses a laser beam to cut the whole stylus and the bar on which it sits from a single pure diamond.

The main aim of stylus design is to combine a perfect shape with low weight and a very smooth surface finish. Ideally, its shape should be similar to that of the cutter used to make the record.

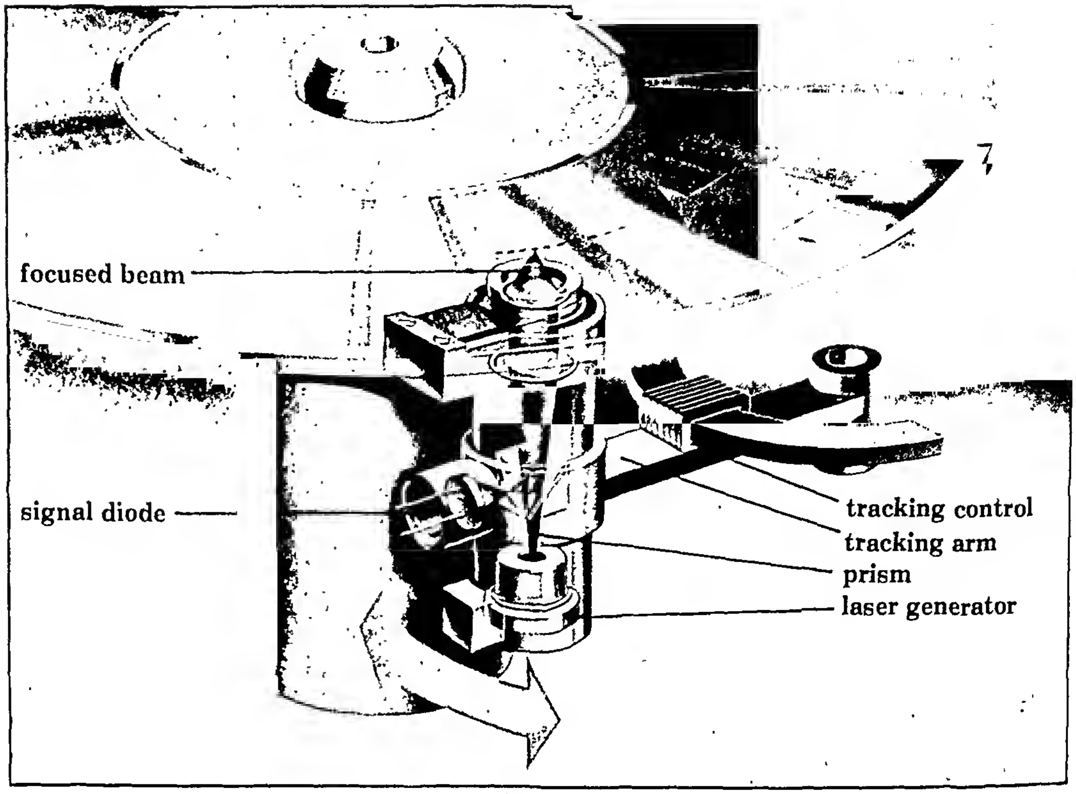
Loudspeakers

Loudspeakers turn one form of energy into a different kind. They turn the electrical signals from the amplifier into sound that we can hear. Hi-fi speakers must produce a complete range of sound from the highest to the lowest notes. And sound is very complex. When a violinist plays a note, a string or strings vibrate and set up vibrations in the air. It is the frequency of these vibrations that gives the pitch of the note. But a note from a violin or any other musical instrument is not composed of vibrations of just one frequency. Each note produces weaker vibrations called overtones of different frequencies. It is these overtones that allow us to tell the difference between a violin playing a note and a flute playing the same note. A good speaker system must cope with as many frequencies as possible.

Different kinds of loudspeakers

Moving-coil loudspeakers have a coil of fine wire

How a laser-operated Compact Disk works. The finely tuned laser beam is focused on tracks only 1.6 micrometers apart on the underside of the disk. The beam is kept in position by a focusing coil in the head of the tracking pillar. This beam is focused so accurately on the surface of the disk that any dirt or grease on the transparent plastic outer coating is out of focus and does not affect the reproduction. It is said the laser beam control system is so accurate that a Compact Disk would still play perfectly with a one-twelfth inch (2 millimeter) hole drilled through the playing area! The disk is only 4¾ inches (12 centimeters) in diameter.



attached to a cone of stiff paper. Electrical signals from the amplifier go through the coil and make it vibrate. The paper cone vibrates with the coil, and the cone's vibrations disturb the air around it, thus making the sound waves we hear.

The box in which the speaker is housed contains different units that handle different parts of the sound range. There are often three separate speakers, the "woofer," the "squawker" and the "tweeter." To produce plenty of sound at low frequencies, a large mass of air has to be moved. This means that the "woofer" which produces the low notes is the largest of the speaker units. The "tweeter" which produces the highest notes is the smallest.

Stereo headphones have become very popular. Listening to music through a headset is quite different to listening to sound waves from a loudspeaker. The sound goes directly into the ears, giving a strong feeling of lifelike quality.

Compact Disks

Compact Disks are a new form of high-fidelity sound. They are only 4¾ inches (12 centimeters) in diameter, but they play without stopping for up to an hour, and the quality of the music produced is superior to that coming from any other kind of record. It is also almost impossible to damage them in ordinary use.

Compact Disks are DIGITAL. All ordinary music reproduction systems, whether tape or disk, are ANALOG. Analog electrical signals are continuous and are stored as wiggles in a record groove or magnetic variations on a tape. These wiggles or magnetic variations are turned into alternating current. The waveform of this current is a direct and continuous replica (analog) of the sounds that created them.

In Compact Disk digital recording, the waveforms produced by the music are measured for frequency and strength 44,100 times every second. (In a more leisurely way, you can take your temperature with a thermometer at hourly intervals and note the results. You can then plot a graph by joining the readings.)

The speed needed to record the values of the sound requires computers and their binary system. The pulses of sound are coded as a series of numbers, or digits, in binary form. The binary code recognizes only two digits, 0 which stands for no pulse and 1 which stands for a pulse.

In the Compact Disk, the laser beam reads tiny pits in the shiny metal surface of the disk. This produces a stream of binary numbers which can be decoded into the usual analog signals that drive loudspeakers. The digital system is less prone to distortion, noise and speed changes.

But the Compact Disk is only one among a stream of new ideas in the constant search for near-perfect hi-fi sound.

See also: LASER, LOUDSPEAKER, MICROPHONE, NOISE MEASUREMENT, RADIO, RECORD MANUFACTURE, SOUND

High-Speed Photography

There may be times when you would like to take a picture of something that is moving so fast you can hardly snap the camera in time. This is where high-speed photography comes in. The technique allows you to photograph things that the eye could not follow.

The dragonfly is known to have a very fast takeoff when it starts its flight. If you tried to photograph this action with a still camera, you would get little more than a blur. The shutter of a still camera cannot work faster than 1/1000th of a second. This is too slow to catch a bullet traveling (at three times the speed of sound) through space, for example.

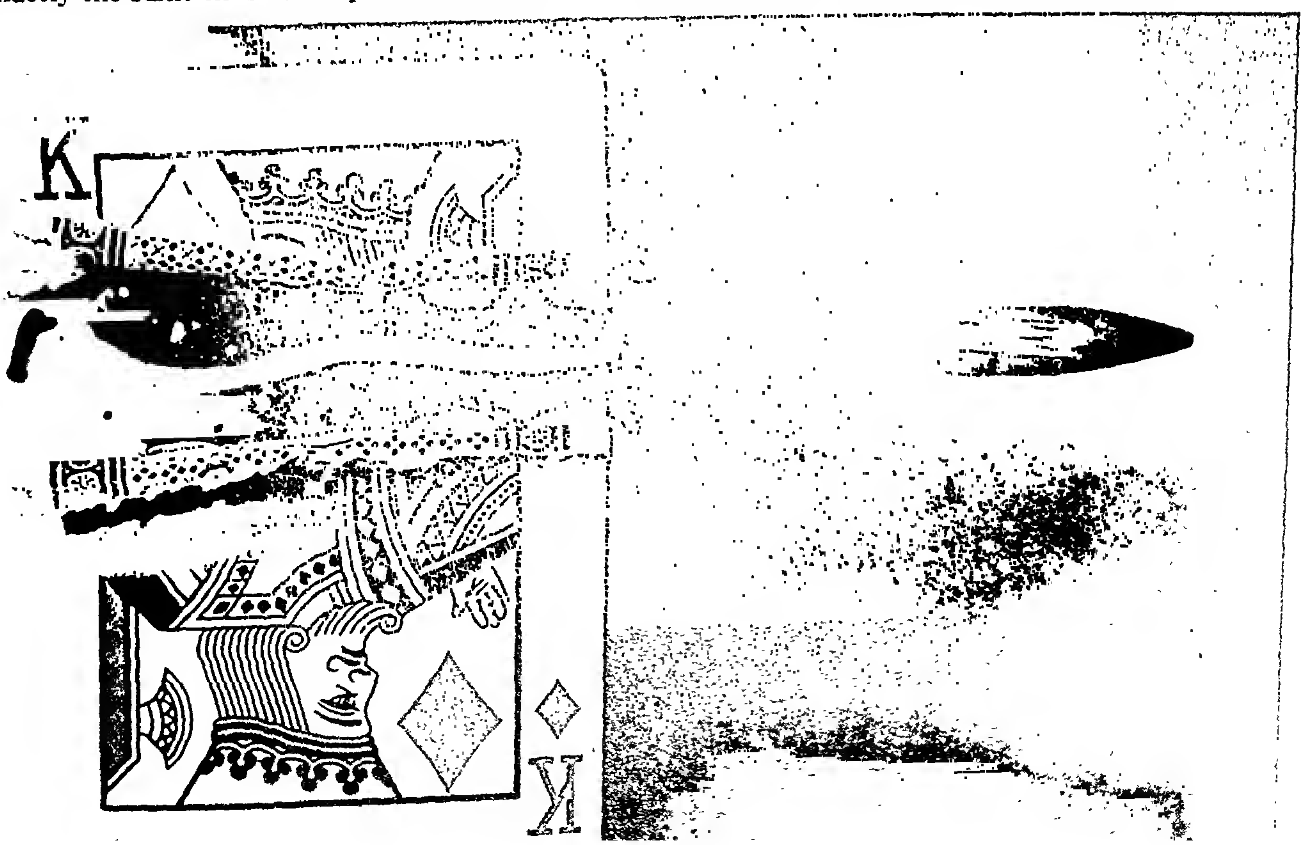
Short exposure
High-speed photography gives the shortest possible exposure time to what is being taken. This means that light from the subject will fall on the film for a very short time. To make up for this, very strong extra light must be put on the object or scene. Such additional illumination is usually a flash, which must be triggered at exactly the same time as the picture is taken.

Flash equipment
There are several kinds of flash equipment. Flash gur use bulbs or cubes, which produce a flash lasting fro 1/80th to 1/100th second. An electric discharge tub gives a flash for 1/75th to 1/1000th second. It is th xenon-filled discharge tube that best answers the ligh problem for high speed photography. These tubes ar connected to a specially designed control that make the flash extremely short—only 0.5 microsecond (hal millionth of a second). The stroboscope, or strobe, i also very effective. It gives 4000 flashes per second, on after the other, and so can catch very rapid motion.

In a high speed camera, the film passes through i continuously (like a movie camera). Of course, ther is some motion as the film moves, and this i compensated for (corrected) by the optical technique o rotating mirrors or prisms. Although both film anc optical compensation move, they remain stationary ir relationship to each other. This avoids blurring.

See also: CAMERA, FLASH GUNS

Below: A bullet passing through a playing card is a good example of high-speed photography.



Holography

Holograms show a scene or object in three dimensions, with depth as well as width and height. You can walk around a projected hologram and see what is on it from every angle. This can be fun as an art form, but holography also has many helpful and important uses in medicine, science and business.

Holograms are three-dimensional images recorded on a light-sensitive film or plate through the technique of holography. They are something like the negative in photography, but they do not make a print when developed. In fact, holograms must be lit up by a beam of light to be seen properly. Then they give a complete reconstruction (rebuilding of the original) in depth, height and width of a scene or object.

The word hologram comes from the Greek prefix holo- and the suffix -gram, and means "complete record." This name is a perfect description. When you look at a projected hologram, you can move sideways or back and forth, or cast your eyes up and down. Because the image is whole, it will change from every angle, just as it would if you were looking at the real thing.

Since the 1970s, exhibits and displays of holograms have been held in art galleries and other public plac Many people have visited such displays.

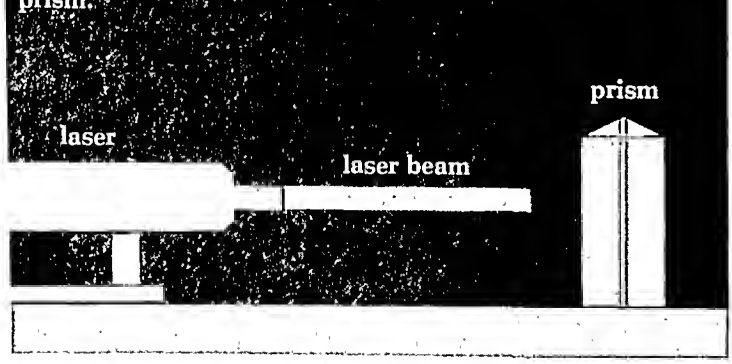
How holography works

The idea of holography was first thought of by t Hungarian-born, British physicist Dennis Gabor 1947, but there was no equipment to make his id work until the invention of the laser some 12 yea later. Holography uses laser light to photograph a reproduce objects in three dimensions.

In order to understand how holography works, it necessary to know a little about how light behave Visible light travels through space as waves, and t different wavelengths give the different colors. Lig moves in a straight line at a steady speed of abo 186,000 miles (about 300,000 kilometers) per secon but it can be bent by an object such as a lens or pris White light is actually made up of a spectrum (range) colored light.

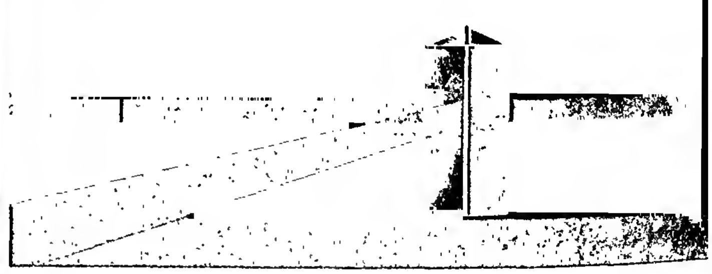
Everything you see was a pattern of lights just t tiniest fraction of a second before your eyes and bra turned it into an image. Scientists tried for many yea

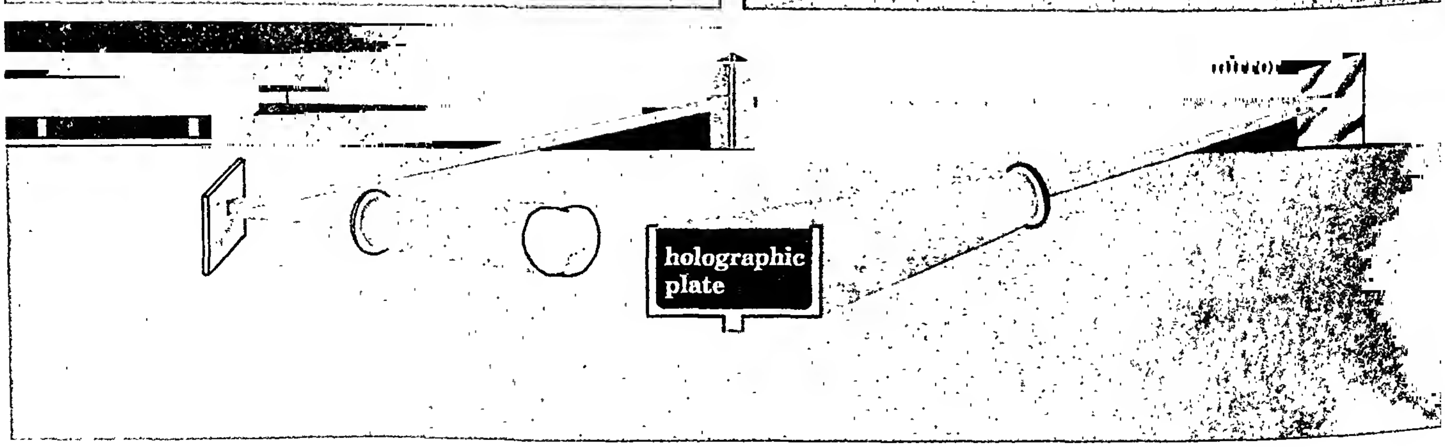
Below: These three diagrams show how a laser beam is split into two in preparation for the making of a hologram.



All holographs start life in a laser tube. This gives out a beam of concentrated light, which is aimed at a prism.

The purpose of the prism is to split the beam in two —a simple optical procedure achieved by the refractive power of the prism. The two beams are then directed off in different directions—they have different work to do.





stop the moving light waves and to record them in is still state. The idea was to release the waves at a ter time, when they would continue on their way to eet the eye and form the images you see.

The big problem in making this happen was that the ources of light, such as the sun or electric bulbs, give nly white light. This light, being composed of many olors, distorts (twists out of shape) depth. What had to e done was to produce a pure light of a single color.

aser light

he invention of the laser solved this. Lasers produce a ery pure and concentrated (firm and dense) light of one requency, that is, with all its waves in step with one nother. This gives one color.

So the hologram can be said to be an image in which he light waves have been stopped. The laser beam is he instrument that releases the waves so that they can gain form into an image.

he divided beam

Vhen a hologram is made, the laser beam is split into two. One of the beams is directed at the light-sensitiv film or plate. This is called the reference beam. Th other is directed at the object or place. This is called th object beam. These two beams meet at the holographi plate. Their wave patterns combine and becom stationary.

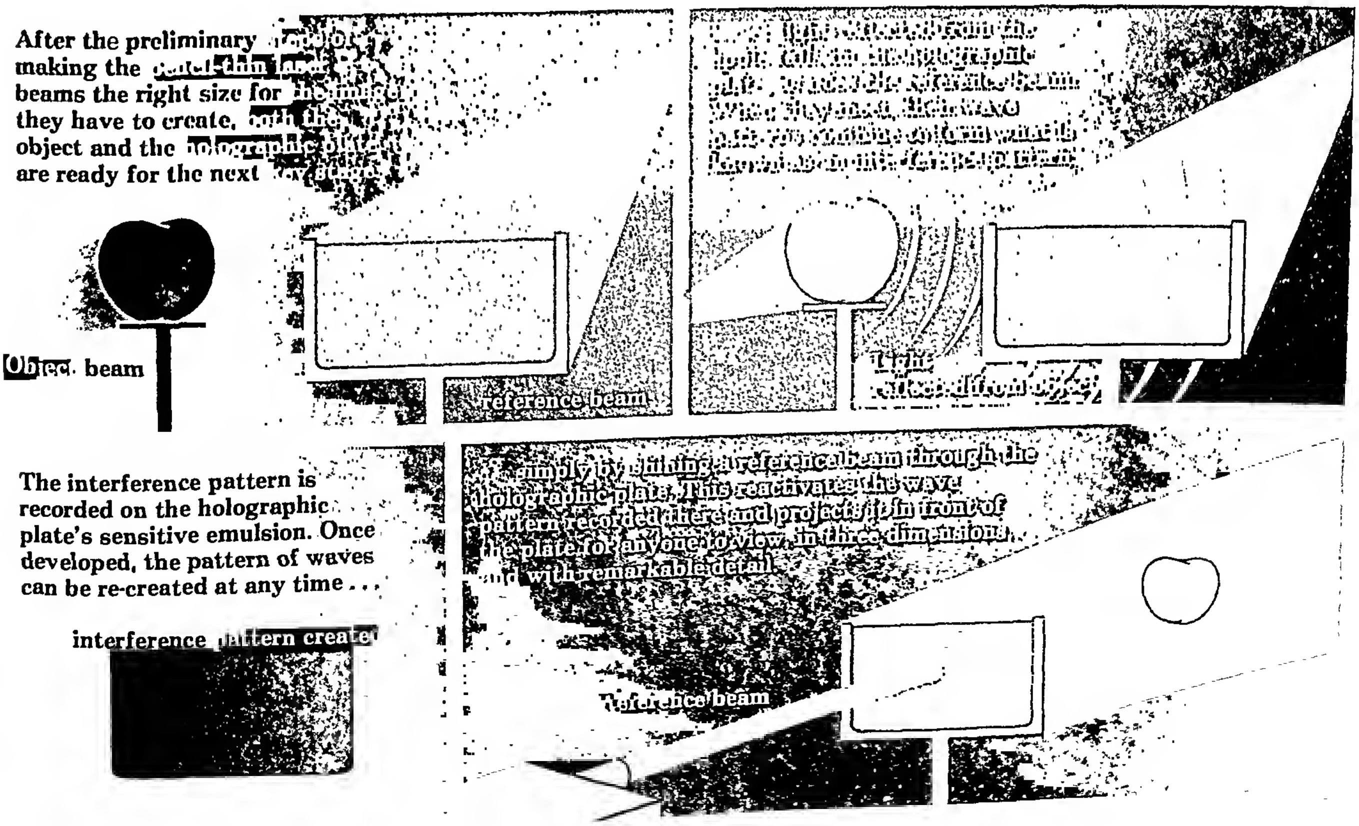
These patterns would only look like stripes an smudges if seen under a microscope. But when they ar bathed in laser light at any later time, the waves tak up their travel where they left off, and enable us to se the image.

Real in a way

Even though holograms are fully three dimensional, they have one big drawback to looking entirely real. This is their color. They are usually all red or all green, because red and green are the pure light produced by the laser beam. This can be rather odd for a banana or a cat, of course, though it suits a rose or a traffic "go" signal. Full natural color is possible, but at present it is too expensive for common use.

Another problem with holograms is that the surface of the image is not smooth. In fact it has a pattern called speckle, which is caused by dust particles in the air and on glass. It is very hard to avoid speckle, no matter how carefully dust is removed. This makes the

elow: The first three diagrams show how the ologram is made; the final one illustrates how it is rojected for viewing.



image's surface appear rough, even if the original object had been smooth.

Uses in daily life

One of the important practical uses of holography is in surgery, especially the removal of tumors (growths) in the body. A doctor must plan this kind of operation in detail, and it is hard to visualize (see in the mind) how deep the tumor goes. X-rays and scans can show only its overall size in width and height. A hologram shows the exact extent of the growth, and gives a clear view of it without any obstruction from the organs in front of it or behind it.

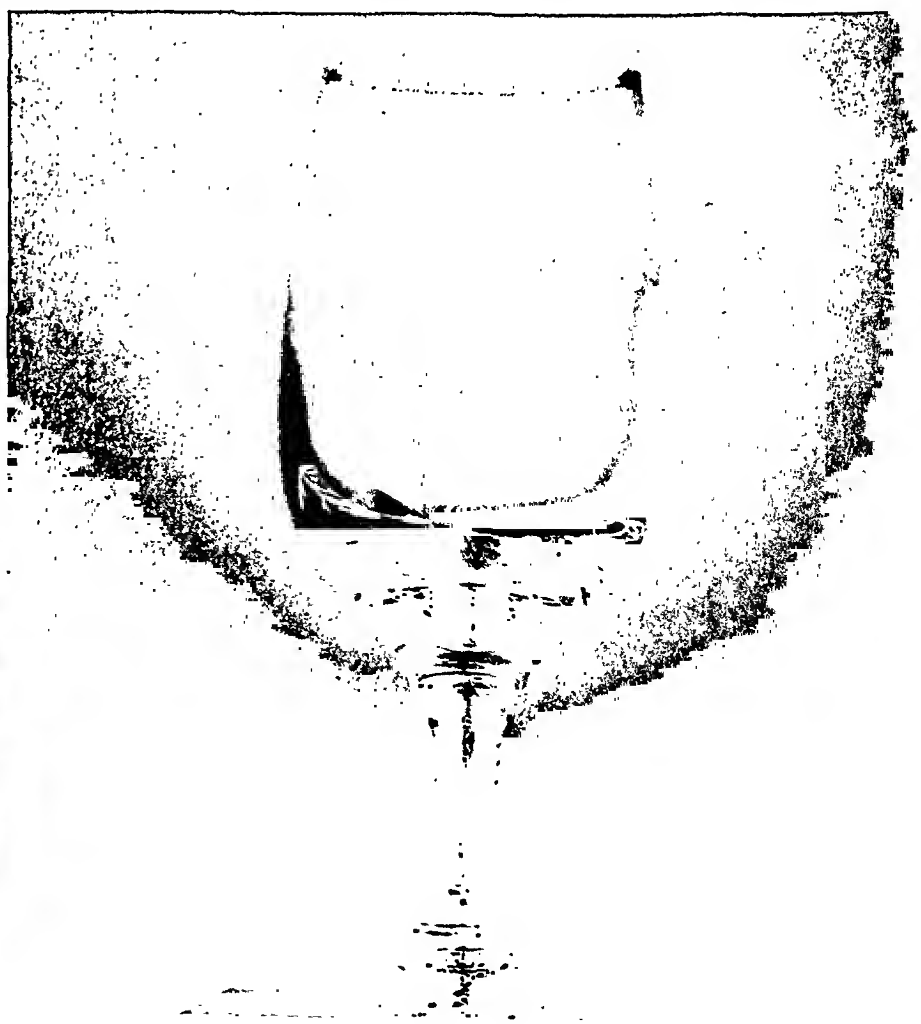
Another medical use is in dentistry. The molds or plates used in making false teeth are very bulky, and take up a great deal of space for storage. With a hologram of a plate, a dentist can take the exact measurement needed. The awkwardly shaped mold is replaced by a hologram no bigger than a playing card.

Holography allows scientists to study complicated processes step by step and in great detail. For example, they can now watch the growth of crystals, which has long presented a problem. They can also find out exactly how fuel burns inside an engine, and they can discover the tiniest faults in metal under stress, such as the supports for bridges and oil rigs. Architects can send three-dimensional views of the houses and buildings they design to their clients. Then it is easy for the clients to visualize the finished structure.

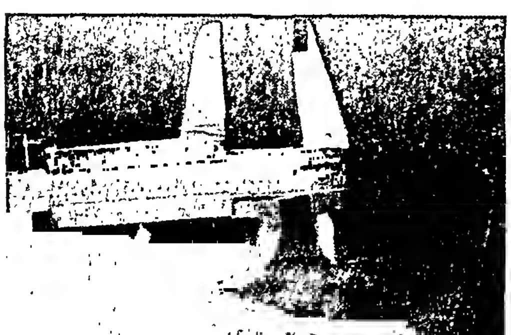
Holograms can combine record keeping with checking out in supermarkets. The way it works is that a scanner reads the printed code that is now on almost all packages. The advantage is that the hologram can find the code anywhere on the package, without the checkout person having to hold it in any special position. The system not only adds up the bill, but also makes a record of what has been sold. This tells the manager when to order more stock and helps tell which products are popular and which are not.

See also: LASERS, LENSES, LIGHT, PHOTOGRAPHIC PROCESSING, SURGERY

Right: This holograph of a wine glass looks like the real thing—except that it is a somewhat unnatural green. This is the result of the color of the laser beam needed to project the image.



Below: A holograph of a dental plate. The recorded image is so accurate that measurements can be taken in all three dimensions. Unlike the real plate, which is bulky, the holographic film is flat, thin and small.



Hydraulic Mechanisms

Hydraulic machines are operated by liquid under pressure. The old water wheels that were used to grind corn were hydraulic machines, so are the turbines in hydroelectric stations. Most of today's machines use a liquid to send a force from one place to another, sometimes quite a distance away.

To understand how hydraulic machines work, it is necessary to understand two basic principles. The first is that it is almost impossible to compress (squash) a liquid, even when it is subjected to very high pressure. The second was discovered in the 17th century by a French scientist called Blaise Pascal. It says that when pressure is applied to a liquid in an enclosed container, the pressure is sent in every direction.

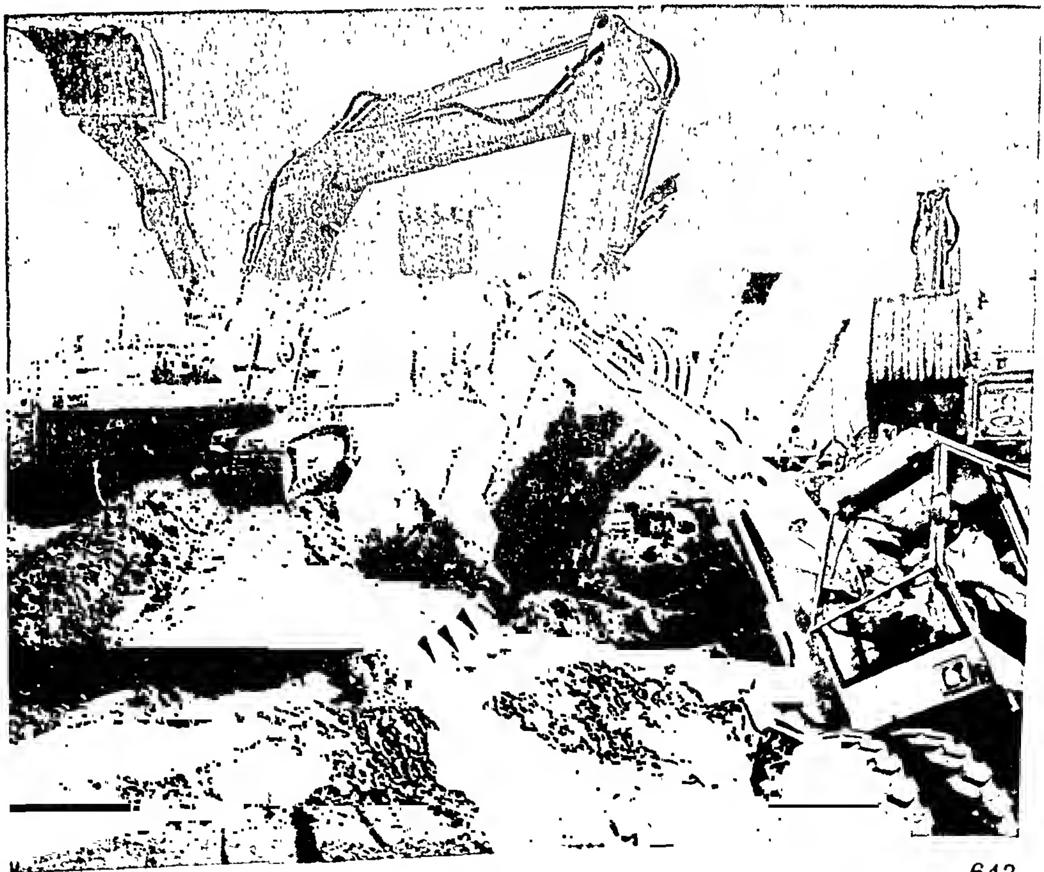
Imagine two upright cylinders of the same size, joined at their bottom ends by a tube. In each cylinder is a piston that fits tightly in its cylinder. The system is filled with liquid and each piston rests on the surface of the liquid in its cylinder. If one of the pistons is pushed down, it will push the liquid in its cylinder down. As the liquid is pushed down through the tube, the second piston will be pushed upward with the same force that was used to push the first piston down. The force ha been transmitted (sent) through the liquid.

The distance that the first piston moves down, will b the same as the upward movement of the second pistoı This force can be sent over long distances, aroun corners and into places that are difficult to get at This gives hydraulic power a great advantage ove mechanical power, which needs gears or links for ever change of direction.

Today, hydraulic power is used in thousands o industrial jobs from powering giant presses to th landing gear on airplanes, from huge cranes to th brake systems in our automobiles.

Lifting heavy loads

Hydraulic power is at its most useful in dealing witl heavy loads. The two cylinders we have just discussec were the same size. Ten pounds of pressure on one piston produced a 10-pound lifting force on the othe piston. But what would happen if the second pistor were twice the size of the first? Suppose the first piston had an area of 10 square inches and the second had an area of 20 square inches. The pressure on the first piston would be 1 pound per square inch; the upward pressure on the second piston would also be 1 pound per



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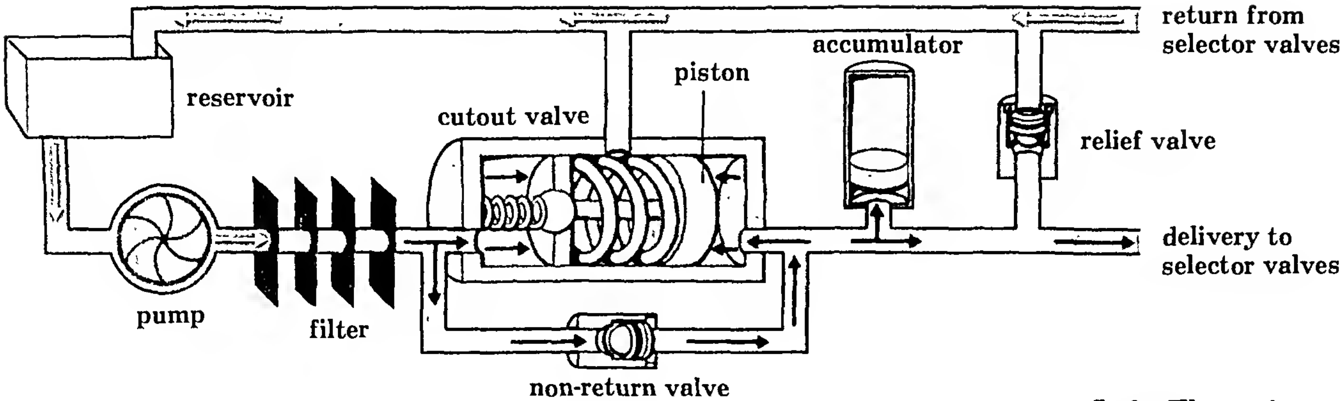
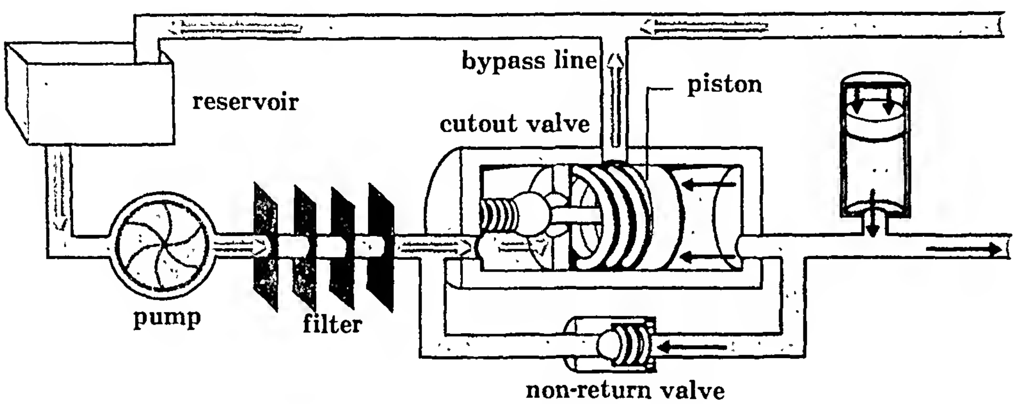




Left: The main parts of a hydraulic power pack. Liquid is pumped from the reservoir through filters and a non-return valve. Normally the cutout valve remains closed, but if the pressure becomes too high, the piston will move to the left (lower diagram), opening the bypass line back to the reservoir. A relief valve (upper diagram) stops a build-up of pressure if the cutout valve fails.

square inch. So the upward pressure on the second piston would total 20 pounds. It is therefore possible to balance a 20-pound weight with a 10-pound weight. If slightly more pressure is put on the first piston, the 20-pound weight will rise.

This is how hydraulic machines work. A small pressure at one end can be made to lift much greater weights at the other end, perhaps a long way distant.

However, it must be noted that to lift a 20-pound weight by 1 inch, the smaller piston would have to be pushed down 2 inches to displace the required volume of liquid. The liquid is being moved from a narrower cylinder to a wider one.

How hydraulics began

Although Archimedes did some research into hydraulics as early as 250 BC, it was not until the late 18th century that Joseph Bramah made the first known hydraulic machine. It was a hydraulic press that had a large cylinder with a piston inside it. The piston had a ramrod attached to it which squeezed the material to be pressed. Pressure was built up by a hand pump, and water was the liquid used.

Since that time, the use of hydraulic machinery has expanded very rapidly to every branch of engineering. Hand pumps have been replaced by power-driven pumps as a source of pressure on the smaller piston. Present-day hydraulic systems use a light mineral oil as the liquid because it has a low freezing point and also serves to lubricate the machine.

The part of the hydraulic system that is concerned with the pressure and supply of the liquid is called the power system. This part is often supplied by manufacturers as a separate unit called a power pack. Power packs can be made in various sizes to suit the pressure and volume of liquid needed to operate a particular machine.

Most hydraulic power packs consist of a reservoir for the liquid, a power-driven pump, a filter, a relief valve, an accumulator, a cut-out valve and a non-return valve (see diagram). The reservoir holds liquid for the pump. The pump builds up the required pressure. The filter makes sure that the liquid is free from any foreign matter, while the accumulator smooths out any changes in pressure. A cut-out valve is needed to make sure that when the maximum pressure is reached, the liquid is by-passed back to the reservoir. The non-return valve is added to the system to make sure that there is no danger if the cut-out valve fails to operate.

Selector valves are the means by which a hydraulic machine is controlled.

The use of hydraulic machines

Today, hydraulic machinery does thousands of industrial jobs. A large oil tanker of 250,000 tons has some 22 miles (35 kilometers) of piping and over

100 actuators (control mechanisms) for hydraulic machinery. The hydraulic selector valves are mounted on a huge console, and each valve has an indicator which shows whether it is open or closed. This allows the oil to be pumped in or out of the ship with a minimum of operators.

Modern airliners use hydraulic equipment to lower and retract the landing gear and steer the nose wheel, in addition to working the flaps or air brakes, wheel brakes and flying controls such as the ailerons, rudder and elevators.

Power presses are almost solely operated by hydraulics, as is much of the equipment on bulldozers and trench diggers.

Below right: A remotely controlled mechanical arm that is worked by hydraulic pressure. The feed pipes are at the top left corner.

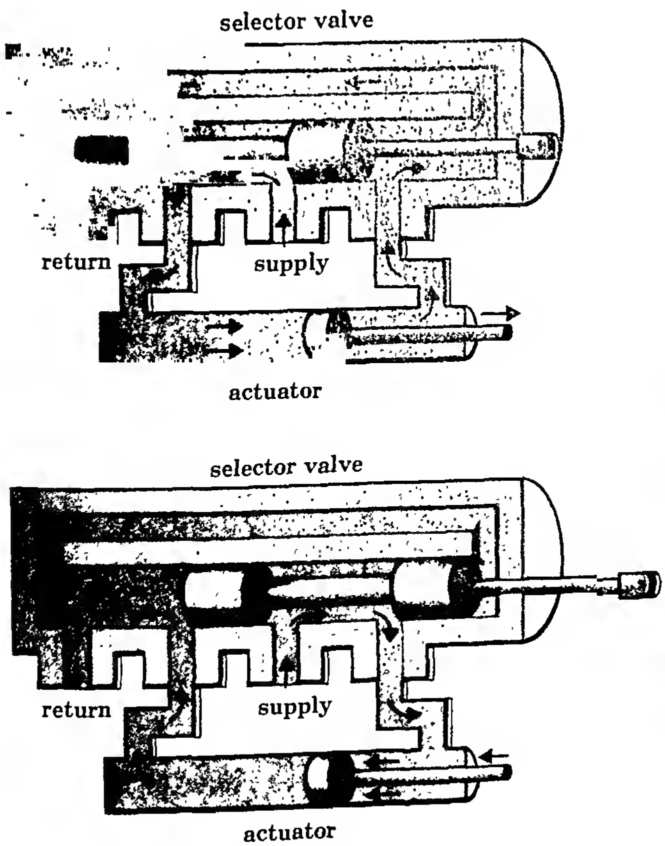
Below: Hydraulic systems can be made to work in different directions. The diagrams show how a hydraulic selector valve operates. The position of the selector valve piston determines whether the actuator will move to the right (upper diagram) or left (lower diagram). The arrows show the direction of flow of the liquid.

Hydraulic brakes

Almost all the automobiles in use today have hydraulic brakes. When the driver presses the brake pedal, he is applying a force to a piston in a liquid-filled cylinder. This is the master cylinder of the braking system. From the master cylinder tubes containing liquid run to each wheel. At the wheel ends of the tubes are other cylinders with pistons. It is these wheel pistons that produce the pressure that operates the brakes themselves. A light push by the driver's foot causes a strong push by the brake shoes or brake pads.

Another important use for hydraulics is in manipulators, machines that allow human operators to "feel" and "handle" objects at a distance. These hydraulic manipulators come in a bewildering variety of shapes and sizes. Some are like enormous arms 50 feet (15 meters) long, such as those used by astronauts in the space shuttle for positioning and collecting satellites.

See also: BRAKES, POWER STEERING, PUMP, SERVOMECHANISM, VALVE

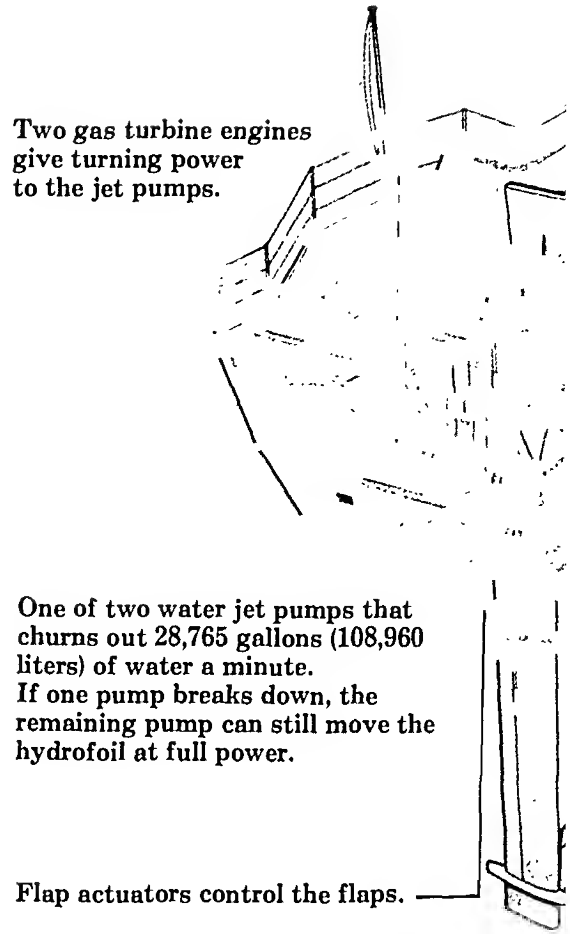


Hydrofoil

A hydrofoil boat is a vessel that skims over the water at high speed. The hull of the boat stands on wing-shaped structures called hydrofoils. As the craft gains speed, the hydrofoils lift the boat's hull clear of the water in the same way that wings lift an airplane into the air.

As you know, walking in water is hard work. Water has a much greater resistance to anything passing through it than air does. Water is several hundred times as dense as air. This is why airplanes are much faster than ships. Most of a boat's engine power is spent in overcoming water resistance.

An airplane's wing is shaped to lift the plane from the ground and keep it in the air provided it travels at a high enough speed. A hydrofoil does exactly the same. Like an airplane wing, a hydrofoil is curved more on the top than on the bottom. This means that the water passing over the top of the foil has farther to go than the water passing underneath. The water on top has to speed up in order to reach the back edge at the same time as the water which travels along the shorter path below. The faster the water on top moves, the lower its pressure becomes. This means that there is more pressure below the foil than on top. The hydrofoil is pushed up, lifting the boat with it. And the faster the hydrofoil moves through the water, the more it is pushed up.



The surface piercing hydrofoil

This design is by far the most popular for civilian use because it is simple to design and operate. The surface piercing foils are roughly V-shaped. Part of the foils is always above the water as the craft moves forward through the peaks of the waves. If lift is lost due to the hydrofoil breaking through waves, the craft sinks slightly lower in the water. This means that more of the foils is in the water, giving more lift.

Large numbers of passenger ferries of this type are now in service, mostly in rivers and lakes. But a 200-ton naval hydrofoil has demonstrated that the surface piercing design can also operate in the open sea, provided the waves are not more than about 12 feet (4 meters) high.

Fully submerged hydrofoils

In this type of design, only vertical struts pierce the water surface. The hydrofoils themselves are completely under water and the boat looks as though it is on stilts.

This kind of hydrofoil gives a smoother ride through the water than the surface piercing craft. The fully submerged foils are at depths where the action of the waves does not greatly affect them. But a control system is needed to keep the craft from crashing d on its hull. In order to keep the boat at a given he above the water when it runs into waves, the angl which the foils cut through the water is varied. A s device pointing ahead of the craft reads the heigh oncoming waves and selects the correct hydrofoil a to give the necessary lift.

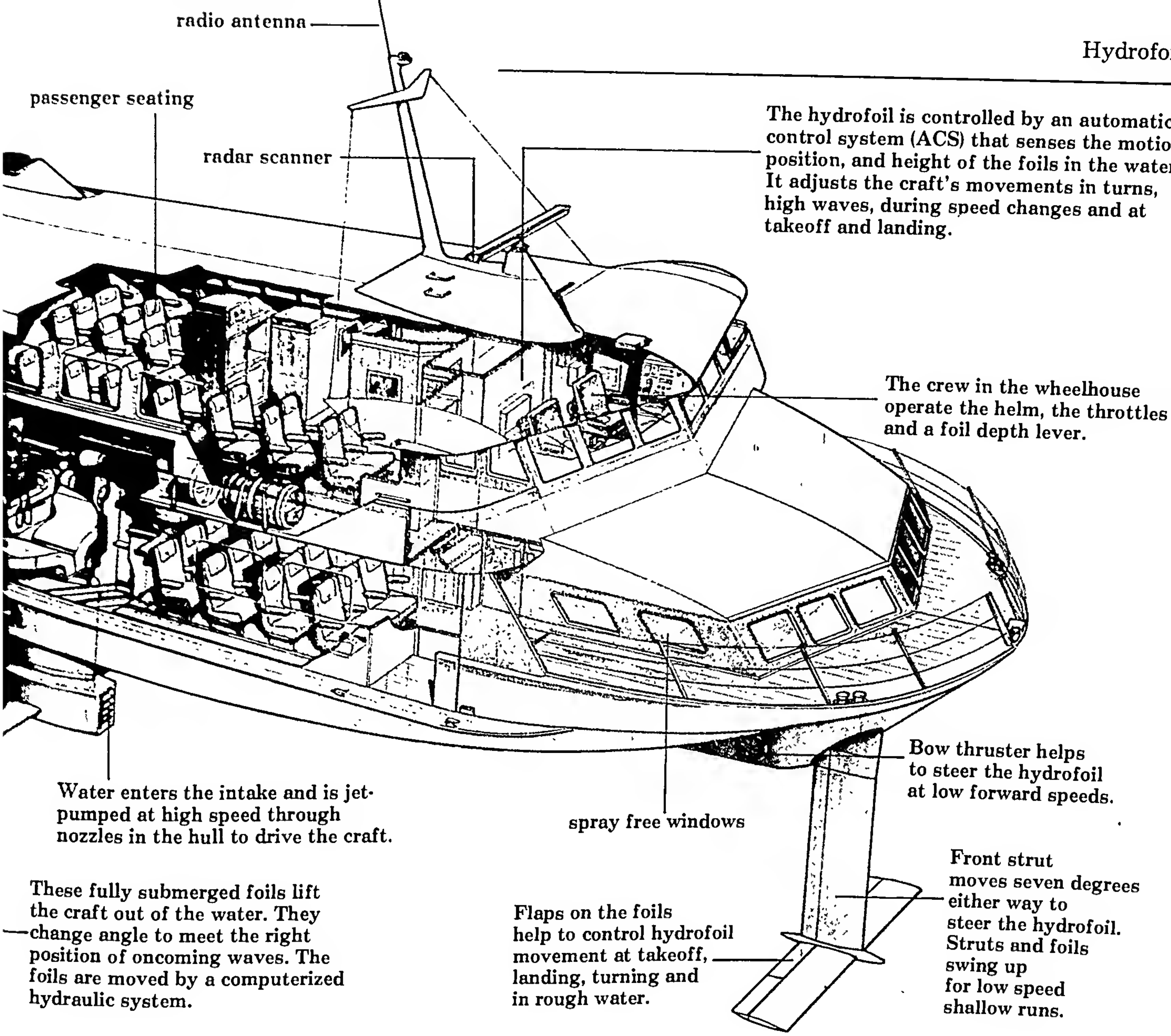
The U.S. has built large naval craft of this type. S have hydrofoils that can swing up out of the wate allow the boat to float like an ordinary craft whil shallow channels.

Ladder hydrofoils

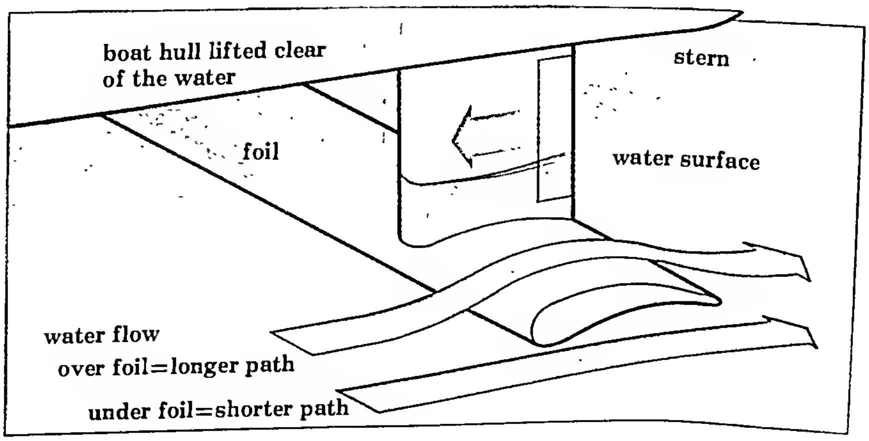
An early type of hydrofoil was the "ladder" type. T had several hydrofoil "rungs." The more rungs t were submerged, the greater the lift. An early hydro boat of this type was the Bell-Baldwin HD4 whic 1919 reached a speed of 60 knots on the Bras D'Or la in Canada.

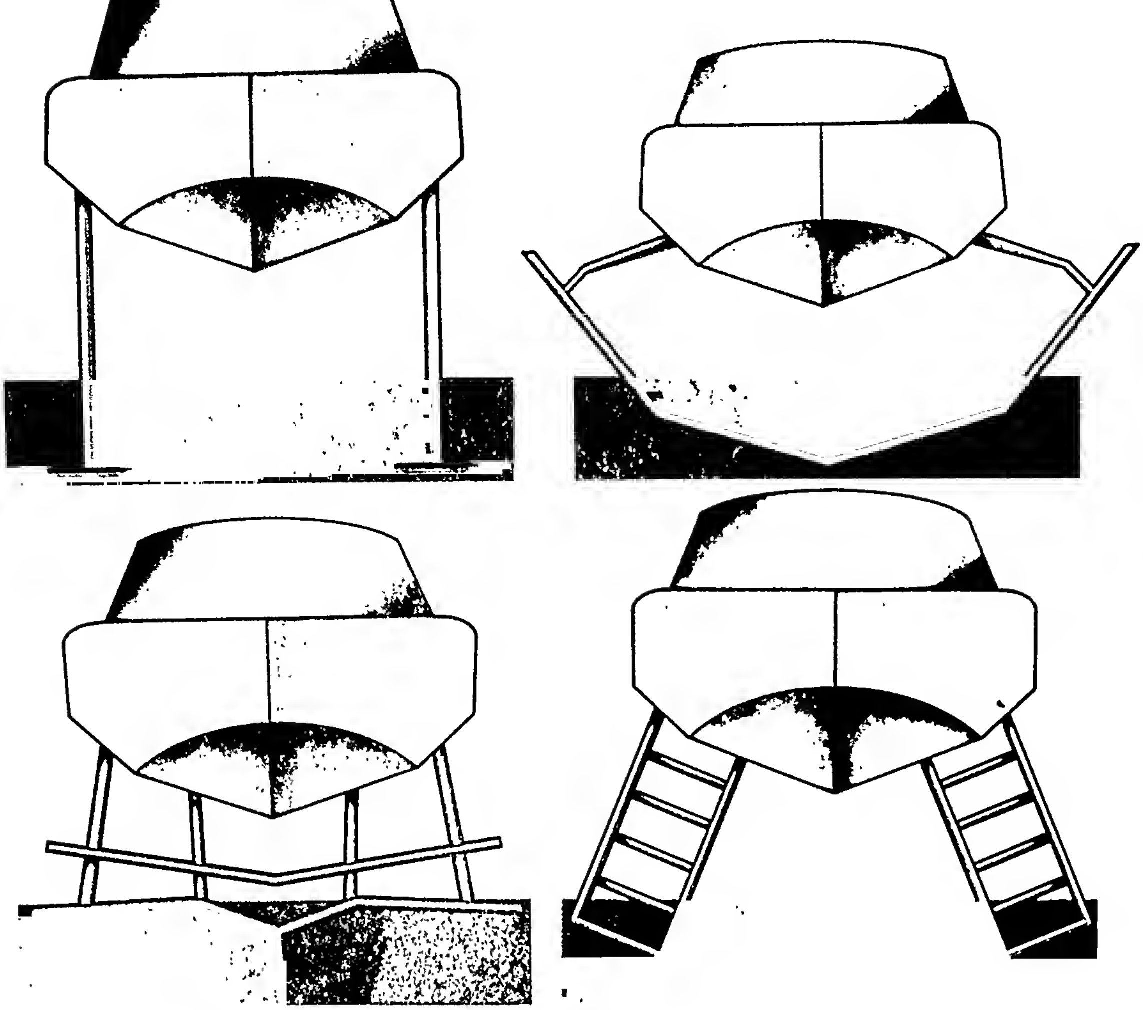
Propulsion

Power units for hydrofoils are usually diesel engi which drive propellers at the end of long shafts. (turbines are also used to pump water out thro



Right: Hydrofoils work in water in the same way wings on airplanes work to lift them in the air. A hydrofoil speeding through water splits the flow. The water flowing over the longer curved upper surface speeds up to reach the far edge at the same time as the water moving along the shorter path below. The faster the water moves past the hydrofoil, the lower the pressure on the top surface. The hydrofoil lifts the boat.





Left: The hydrofoil acts as a wing in water. Some hydrof are surface piercing The ends of the foil break the surface as the craft moves forward. When lift i lost as the hydrofoil breaks through the waves, the craft sinl lower. This gives m lift. In other design the foils remain submerged. The amount of lift is controlled by changi the angle of the foil The pictures show f different types. The "ladder" type was o of the early hydrofo

nozzles in the hull which will then drive the craft.

In some designs, most of the hull weight is supported by a large foil or foils placed forward in the hull. In others, the large foils are toward the stern. In both cases the remaining weight is supported by a smaller foil which can be turned to steer the craft.

Some problems

There are still some problems to be solved in hydrofoil construction. At speeds above 50 knots, the rush of water across the top of the foil causes cavities (small holes) to form along the foil surface. These cavities fill with air or water VAPOR and cut down the lifting force of the hydrofoils.

When the craft is traveling fast, the water pressure on the top foil surface may drop so low that air from above the surface of the water may be sucked down the strut and along the foil. This also causes variations in the lifting force of the hydrofoils.

The future of hydrofoils

Hydrofoils carry over 30 million people every year in 50 countries, usually as ferries for short, fast journeys. The U.S. Navy has hydrofoil boats in production, and it is thought that ships up to the size of destroyers may be possible in the near future. With computers controlling the foils, this could be the ship of the future.

See also: AIR CUSHION VEHICLES, AIRFOII

Below: The Jetfoil carries 250 passengers in two decks. The hydrofoil can cruise in waves 12 feet (meters) high. The craft is powered by high-pressu water pumps driven by two gas turbines. Jetfoil' struts can be raised so that she can work as an ordinary craft in shallow water. She can cruise at 50 miles (80 kilometers) per hour while remaining quite steady in the water.